Vol. VI Part 3 August 1954

THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY

Editorial Board

D. RUSSELL DAVIS
R. C. OLDFIELD J. W. WHITFIELD
G. C. DREW M. D. VERNON
G. C. GRINDLEY O. L. ZANGWILL

CONTENTS

S. LANER. The Impact of Visual Aid Displays Showing a Manipulative Task - - - - - - 95
R. L. REID. An Illusion of Movement Complementary to the Horizontal-Vertical Illusion - - - - 107
K. R. L. HALL and A. E. EARLE. A Further Study of the Pendulum Phenomenon - - - - 112
ALAN J. GLYNN. Apparent Transparency and the Tunnel Effect - - - - - - - - 125

PUBLISHED FOR
THE EXPERIMENTAL PSYCHOLOGY GROUP
BY
W. HEFFER & SONS LTD. CAMBRIDGE

OCCUPATIONAL PSYCHOLOGY

Editor: ALEC RODGER

April, 1954 Volume XXVIII, No. 2

CONTENTS

The Consistency of Stop-Watch Time-Study Practitioners. By Winston Rodgers and J. M. Hammersley

Experiments on the Acquisition of Industrial Skills. By W. Douglas Seymour

An Approach to the Study of Dial Reading. By G. F. K. Naylor

Retention of Theory as a Criterion of the Need to Reconsider the Theory Content of a Practical Course. By R. W. H. Lubbock

An Occupational Classification for Use in Vocational Guidance. By R. M. McKenzie

Book Reviews

Other Books Received

Annual Subscription 30*s.*

NATIONAL INSTITUTE OF INDUSTRIAL PSYCHOLOGY
14, Welbeck Street, London, W.1.

THE BRITISH JOURNAL OF PSYCHOLOGY

(GENERAL SECTION)

Edited by D. W. Harding

Vol. XLV Part 3 August, 1954 12s. 6d. net

E. E. Jones & J. S. Bruner. Expectancy in apparent visual movement.
W. T. Singleton. The change of movement timing with age.
A. D. B. Clarke & A. M. Clarke. Cognitive changes in the feebleminded.
D. E. Berlyne. A theory of human curiosity.
G. Jahoda. A note on Ashanti names and their relationship to personality.
J. N. Britton. Evidence of improvement in poetic judgement.
W. A. McElroy. A sex difference in preferences for shapes.
W. C. R. Withers. A new tachistoscope and cycling timer.
Correspondence.
Critical Notice: Uppsala Symposium on Psychological Factor Analysis, 17—19 March 1953.
Publications Recently Received.

The subscription price per volume, payable in advance, is 40s. net (*post free*).

Subscriptions may be sent to any bookseller or to the

CAMBRIDGE UNIVERSITY PRESS

Bentley House, Euston Road, London, N.W.1

THE QUARTERLY JOURNAL OF
EXPERIMENTAL PSYCHOLOGY

Vol. VI 1954 Part 3

THE IMPACT OF VISUAL AID DISPLAYS SHOWING A MANIPULATIVE TASK

BY

S. LANER

From the Department of Psychology, University of Reading

A moving film and a filmstrip, composed of line drawings, were compared in respect of their efficacy in imparting instruction about a manual task. Their respective effects were tested by making the subjects actually perform the task. The chief aims of the experiment were, firstly, to determine the manner in which material presented pictorially is utilized in the approach to and execution of the task and, secondly, to assess the special effects, if any, of motion and photographic realism in the presentation.

The approach both to the perception of the material and to the execution of the task was found to be essentially constructive. For this reason much that is usually presented is superfluous while, on the other hand, points of principle necessary to adequate construction are often insufficiently clarified or emphasized. No significant difference between the moving film and the filmstrip presentation was found. It is concluded that aspects of visual aid material, such as motion and photographic realism, which are commonly assumed to be of special cognitive importance, do not themselves play a unique rôle.

I

INTRODUCTION

The increasing use of pictorial, in place of verbal methods of teaching and instructing has raised a number of psychological problems of both theoretical and practical interest. The widely expressed preference for pictorial methods appears to arise out of a fairly generally held assumption that media of communication which are deemed to represent "reality" with a high degree of fidelity are *ipso facto* more likely to make an impact upon the perceiver and, by virtue of this greater impact, produce quicker, greater and more durable learning effects. Although rarely expressed, the psychological implication of this assumption is that the perception of highly realistic pictorial displays is in some way simpler, more immediate, than the perception of a less "realistic" display, let alone of a display consisting of highly abstract symbols, e.g., words.

Now the motion film is typical of what is meant by a highly realistic display. If the above assumptions hold good, then the properties of continuity and represented motion should give the film a high advantage, in terms of learning effects, over both more static and discontinuous display, such as filmstrips and slides, and over verbal and textual display. The advantage should be particularly high when the "reality" represented is itself a moving and continuous one; this would appear to be the case in manual operations forming a skilled performance.

In the present investigation an attempt was made to compare a commercially produced film, showing a skilled task, with a specially prepared filmstrip in terms of relative learning effects. The commentary was controlled by keeping it essentially the same for both types of display. One or the other type of display was shown to each subject once. Then he was required to perform the task shown. The subjects were university students and National Servicemen.

As it was one of the main aims of this study to find out whether pictorial displays do in fact make a greater impact on the perceiver, at what points the impact is greater and wherein it consists, the quantitative analysis of overall learning effects was supplemented by a kind of item analysis and by an assessment of the qualitative nature of subjects' responses. An attempt was then made to arrive at a hypothesis concerning the processes which are evoked by pictorial displays.

II

Methods and Procedures

The task.

The selection of a task suitable for laboratory treatment was governed by the availability of commercially produced film material. A number of other considerations, such as that the task should be neither too difficult nor too easy for the subjects available, and that it should be interesting and meaningful and at the same time unfamiliar to most subjects narrowed the range of possible tasks down to one: the dismantling, repair and subsequent reassembly of a sash-cord window.

The three stages of this task could be considered as each consisting of a number of discrete sub-operations: 8 in the case of dismantling, and 10 and 4 respectively in the case of the repair and reassembly stages. From a pre-view analysis of the film it appeared that the second stage of the task (repair) differed from the other two in level of difficulty, the relationships between individual actions and movements and their ultimate effects not being immediately obvious.

The display material.

For the purpose of this experiment the task-performance as shown in the film was considered to be the "correct" performance.

The film (which was produced by the Topical Film Co., Ltd.) presented the task in a completely straightforward fashion. A short description of the system on which the sash-cord window works and of its component parts was followed by a practically unabridged version of a handyman going through all the motions of dismantling the left-hand part of a window, repairing the broken cord and reassembling the window. The "camera-behind-operator" technique was used throughout. The rate of development was fairly brisk. No part of the operation was repeated, nor was any operation given special emphasis. No use was made of slow motion or of any other special effects. The commentary was equally straightforward. Possible errors were never shown visually and were at most summarily referred to in the commentary. The film has been described by an experienced producer as a medium quality one.

The filmstrip, consisting of 51 frames, was prepared in the laboratory. The intention was not to make it as closely comparable as possible to the typical commercial filmstrip, but to produce a display in which the visual element would be not only greatly reduced by comparison with the film but also lacking in the attribute of represented movement. At first it was planned to select suitable "stills" from the film itself; but the display obtained by this method turned out to be so poor in definition that it was discarded and a black-and-white version prepared instead. The "stills" for this version were obtained by tracing and inking-in enlargements of the original stills, and printing them on 35-mm. stock.

The commentary for the film and the filmstrip were both recorded on a wire recorder, a sound-film projector not being available. The wording of the commentaries for both types of display were virtually identical in phrasing and content.

Subjects and procedure.

Records of performance were obtained from 75 subjects, all of whom were tested individually. Of these 12 were university students; all of them viewed the film. The remaining 63 subjects were National Servicemen (R.A.F.), and, of these, 50 viewed the film, 13 the filmstrip.

The National-Servicemen groups consisted of personnel employed on general and clerical duties; they were in the main of medium intelligence, and their general educational background was very varied, ranging from elementary school to grammar school standard; there were also considerable differences in mechanical skill and experience. The students were generally of above-average intelligence.

Each subject was told in advance that he would be asked to perform the task after viewing. Personal data were collected immediately after the viewing, together with subjects' comments on the display. A model sash-cord window was used for the actual test, the cord being broken on the side opposite to that shown in the displays. A close record was kept of each individual performance, but timing was dropped after a try-out, as it tended to make subjects nervous and also because the method of prompting the subjects whenever their performance came to a prolonged stop rendered the time records virtually useless.

Intelligence test scores (AH4—a written intelligence test containing verbal and non-verbal items) and NIIP Spatial Relations test scores were obtained for 47 Servicemen who viewed the film and for all Servicemen who viewed the filmstrip. Similar scores for the student subjects could not be obtained.

III

ANALYSIS OF RESULTS

1. *Overall Learning Effects.*

Preliminary tests with subjects whose results are not included in this report showed that the responses on the 23 sub-operations of the task could be conveniently classified into seven categories: correct response, major error, prompt, minor error, correct response but out of serial order, omission and importation. The categories are self-explanatory, except for the distinction between major and minor errors. This distinction was drawn on the basis of the character of an error in relation to the task as a whole, major errors being those that would have arrested the performance at some later stage or which would have led to a faulty final achievement; with this type of error the experimenter's intervention was necessary and there is, therefore, no essential difference between major errors and prompts.

Conversion into percentages of totals of correct responses and of prompts and major errors yielded two "scores" for each subject; this made possible a statistical comparison of the main features of the performance in the three groups of subjects. The statistics obtained for correct responses and for major errors plus prompts (in percentages) are shown in Tables I and II respectively.

TABLE I

Group	*Number of subjects in group*	*Mean per cent. operations correct*	*Standard deviation*
Students (film)	12	77·39	15·32
R.A.F. (film)	50	66·23	17·41
R.A.F. (filmstrip) . .	13	58·75	19·82

TABLE II

Group	*Number of subjects in Group*	*Mean per cent. major errors plus prompts*	*Standard deviation*
Students (film)	12	13·38	12·83
R.A.F. (film)	50	19·61	13·37
R.A.F. (filmstrip) . .	13	27·04	11·23

The differences between the mean per cent. operations correct of the student and the two R.A.F. groups are significant at the 5 per cent. level (the values of 't'' being 2·01 and 2·42). There is no significant difference between the means of the two R.A.F. groups for correct responses. As regards errors and prompts, the difference between the student-group mean and the R.A.F. (filmstrip) group mean is significant at the 2 per cent. level; the remaining differences are not significant at the conventional levels.

The absence of significant differences between the two R.A.F. groups suggests that as regards overall learning effects the two types of display used were equivalent. The superiority of the student group must, in all probability, be ascribed to factors other than display effects.

Inspection of the two tables shows that in general the mean percentages of correct responses are rather high and the percentages of errors and prompts correspondingly low. This in turn suggests that both types of display were exceedingly effective in conveying the task. The numerical indices, however, are to a certain extent misleading for the following reasons: (*a*) the conversion into percentages of scores obtained on a task consisting of only 23 sub-operations is not unobjectionable, (*b*) the high scores are almost certainly not due to the display effectiveness alone, but at least partly to related past experience operating during the task performance, (*c*) the overall response scores tend to disguise differences in the adequacy of performance at different stages of the task which might well reflect differences in the effectiveness of the display.

2. *Performance differences within the task.*

The second method of analysis has special reference to point (*c*) above. The method was to pool seaprately the correct responses and the errors and prompts made at each of the 23 sub-operations for each whole group of subjects; these totals were again expressed in percentages. Thus if, for example, all 50 subjects in the R.A.F. (film) group performed the first sub-operation correctly, this would represent a 100 per cent. correct response for the group on this sub-operation.

The results of this analysis are represented graphically in Figures 1 and 2. Figure 1 shows the percentage of correct responses made by each of the three groups on the 23 sub-operations, Figure 2 the percentage of major errors and prompts.

Two points are clearly brought out by this analysis. Firstly, the differences found between the three groups by the preceding statistical analysis are based on

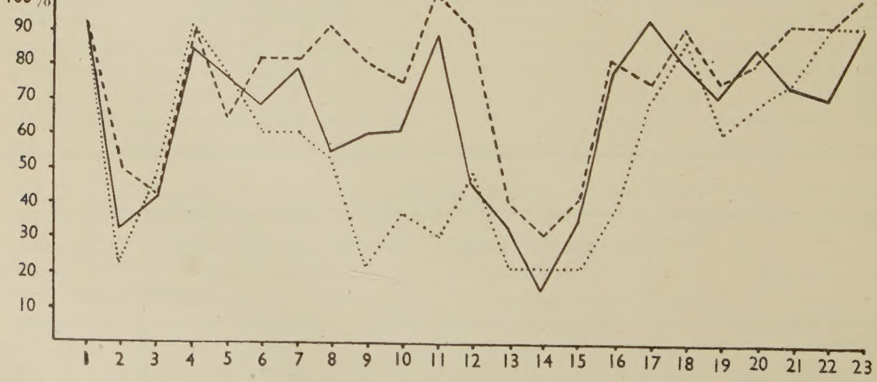


FIGURE 1

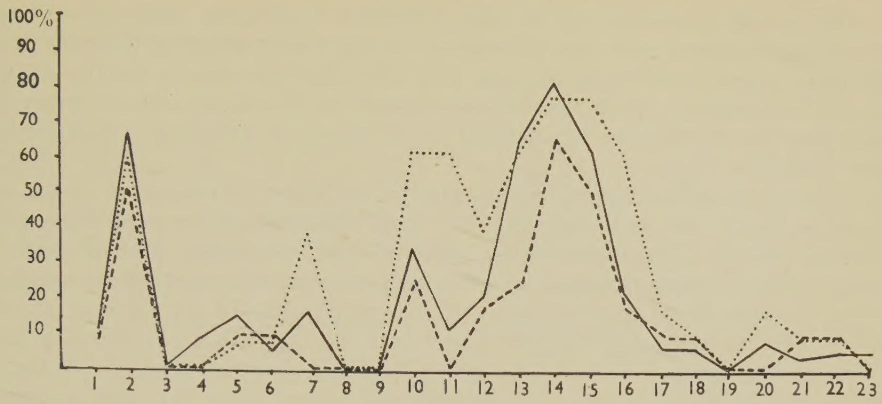


FIGURE 2

fairly consistent trends running through the whole course of the performance. The Student (film) group graph is consistently above that of the R.A.F. (film) group. This group in turn shows up consistently better than the R.A.F. (filmstrip) group. However, the advantages of any group over any other, though fairly consistent, are at most points insignificantly small.

The second point brought out by the analysis is of central importance in the present context. It is quite clear that faulty responses and errors did not occur randomly throughout the performances, but tended to pile up at certain stages of the task. This accumulation is particularly noticeable between sub-operations 9 to 18 and on sub-operation 2; it occurred with all three groups regardless of the type of display used.

3. *Relationship of performances and displays.*

The conclusions that can be drawn so far tell us about the nature of the performance rather than about the performances as related to the displays. Although it is clear that errors and prompts accumulated at certain stages irrespective of what type of display was used for instruction, it does not necessarily follow that these accumulations are due to a failure of communication by the displays; that this was so is only a plausible hypothesis. A further, qualitative, analysis might provide some further leads.

Considering first of all the qualitative nature of the errors in the initial (dismantling) and final (reassembly) stages, the majority of errors and prompts were concerned with performing an operation in a different serial order from that shown in the displays, or with omissions of sub-operations which were not of direct importance to the successful dismantling or reassembly. That alterations in serial order should have occurred is not surprising in view of the general difficulty of establishing such an order, as Bartlett (1952) noted.

Sub-operation 2, which falls into the dismantling stage, requires separate consideration. This sub-operation is that of taking the bottom sash out of the frame of the window and detaching its intact cord, thus permitting access to the second (top) sash, the cord of which had been broken. The errors that occurred here are probably due to two factors. Firstly, the sub-operation falls near the beginning of the task, and it is a common observation that subjects, when confronted with a task, are reluctant to make a move which they feel cannot be easily reversed. Secondly, the removal of the bottom sash is practically identical with the removal of the top sash, which is also shown in the displays. In both displays no clear differentiation is made between these two nearly identical moves, which occur at different stages of the task. It is therefore likely that this lack of differentiation by the displays leads to the jumbling up of the two sub-operations in the process of perception. Clearly, this jumbling must be ascribed to a failure of adequate communication by the displays.

The quality of performances during the repair stage, where most errors and prompts occurred, was radically different from that of performances during the assembling stages. The repair stage performances frequently started with an omission of a less important operation (stretching the new cash-cord before insertion). The next two operations are concerned with the preparation of the "mouse" (a piece of lead hammered round a string which later acts as a "shoelace" for the new cord). The film groups seemed to find little difficulty here, while the filmstrip-instructed subjects fared decidedly worse. It is possible and indeed likely that this was due to the lack of continuity in action of the filmstrip.

The next sub-operation, involving the insertion of the "mouse" into the aperture above the pulley, seems to mark the point where effective communication by both displays broke down. There are several clear indications of this. For one thing, prompts were very much more frequent than errors here—in other words, subjects were completely in the dark what to do next. Secondly, subjects reported "I didn't see clearly" rather than "I have forgotten," or "I didn't remember." All in all, failure of communication, as judged by performance, occurred with 90 per cent. of all subjects regardless of the type of display.

4. *Performance and "audience variables."*

Unless a very naïve view is taken of the nature of perception, it is quite obvious that the failure or success of communication is a function of variables within the responding subject as much as of variables within the display. There is always a possibility of improving communication by altering the variables on one side or the other or on both. Since the present research is chiefly directed towards the analysis of variables in the display, our main concern was with keeping the audience variables controlled. However, the institution of preliminary controls is bound to be a somewhat futile procedure unless some foreknowledge is available regarding the significant variables. It was therefore merely attempted (*a*) to check on the homogeneity of the population with respect to "intelligence" and "spatial ability" at the close of the experiment, and (*b*) to guess at and check on any other variable that might require controlling in future experiments.

Statistical treatment of the scores on test AH4 and on the NIIP Form Relations test, which were available for 47 out of the 50 film-instructed R.A.F. subjects and for all filmstrip-instructed R.A.F. subjects, showed that between these two groups there were no significant differences on either of the tests employed, nor were any such differences found when the verbal and non-verbal parts of test AH4 were evaluated separately. This can be taken as indicative of the fact that the two samples were drawn from the same population.

To check on the possible effects of these "audience variables" the data of the 47 film-instructed R.A.F. subjects were further analysed as follows. First, the mean "correct response" percentages of subjects who scored *above* and *below* average on AH4 were compared. The same procedure was used to compare those who scored above and below average on the NIIP test. Table III shows the differences to be low and not significant statistically.

TABLE III

	N	*Mean per cent. "correct responses"*	*Difference (in per cent.)*	*t*
Above gp. average scorers on AH4	24	70·16	7·16	1·36
Below gp. average scorers on AH4	23	63·00		
Above gp. average scorers on NIIP	22	72·00	10·05	2·01
Below gp. average scorers on NIIP	25	61·95		

The small differences found are in good agreement with the low positive/biserial/ correlation coefficients found in a U.S. film project (Zuckermann, 1949) between scores on a film-mediated knot-tying task and the U.S. Navy General Classification (intelligence) test ($r = 0{\cdot}14$) and between this task and the U.S. Navy Mechanical Aptitude test ($r = 0{\cdot}30$).

Finally, there seemed to be good reasons for assuming that *related* past experience, in this instance mechanical training, experience or private interest, would affect the amount as well as the quality of performance on the task. Since during the experiment every subject in the film-instructed R.A.F. group had been asked whether he had had any mechanical training or experience or whether he was interested in matters mechanical, a statistical check, admittedly rather rough and ready, was possible. This was done by splitting the "correct response" percentages into two sets ("experienced"—"inexperienced") and by comparing the mean values. These values are shown in Table IV.

TABLE IV

	N	*Mean per cent. "correct responses"*	*Difference (in per cent.)*	*t*
"Experienced"	22	73·19	13·23	2·24*
"Inexperienced"	17	59·96		

* The value of *t* found is significant at the 0·05 level.

The significance of the difference is underlined by the fact that out of the 8 subjects in the total group who satisfied the experimenter that they had mastered the principle of the repair stage, 7 fell into the "experienced" group, and only 1 into the "inexperienced."

Although the data here presented indicate that while related past experience is a significant variable and must therefore be controlled, it should not be hastily concluded that "intelligence" and "spatial ability" (as measured by tests) are not significant variables. The scores of the R.A.F. subjects all fell within a rather narrow range, and it is possible and indeed likely that, e.g., very highly endowed subjects would (*a*) gain more information from the display, and (*b*) show more versatility in performance.

Commentary effects.

Within the framework of this experiment no direct provision was made for an estimation of the relative contributions made to learning by the visual and auditory channels of the display material. In comparing the effect of the film and the experimental filmstrip the verbal commentary was merely kept constant for both types of pictorial display.

It was, however, decided to carry out a rough check on the commentary at two levels of assumed difficulty. At the lower level of difficulty three figures mentioned by the commentary were singled out, and subjects were asked (after the performance) if they could recall these figures. Since none of these figures could have been obtained from the pictorial display, it could be assumed that their recall would be based on a "pure" commentary effect. Table V shows the percentages of subjects in each group who recalled literally all three, two, one and no figures respectively.

TABLE V

	Figures recalled (in per cent.)			
	None	*One*	*Two*	*All*
R.A.F. (film) group	4	20	48	28
Student (film) group	—	8·5	50	41·5
R.A.F. (filmstrip) group . .	30·7	15·4	23	30·7
All subjects	8	17·3	44	30·7

From this table it is obvious that nearly 75 per cent. of all subjects tested recalled accurately two or all figures. At a comparatively low level of difficulty it is clear that the commentary is highly effective.

Under the term "high level of difficulty" we arbitrarily subsumed four items of technical terminology used in the commentary: the guard bead, the parting bead, the pocket piece and the "mouse." The data for the two R.A.F. groups only were available. The percentage of correct recall of each item are shown in Table VI.

TABLE VI

	Frequency of recall (in per cent.)			
	Parting bead	*Guard bead*	*Pocket piece*	*"Mouse"*
R.A.F. (film) group	10	10	4	44
R.A.F. (filmstrip) group . .	15	—	—	69

Only one single subject in the R.A.F. (film) group recalled accurately all the items, and two further subjects recalled 3 items correctly. In the filmstrip group no subject recalled all or even 3 items accurately.

However, there was no dearth of "substitute" technical terms, and practically no subject was prepared to admit that he recalled no names of technical parts: 8 different substitute versions were volunteered for the guard bead, 23 different substitutes for the parting bead, 8 for the pocket-piece. The most interesting and the most amusing transmutations occurred with the term "mouse," which was recalled accurately most often. The substitutes offered included (apart from descriptive suggestions) such terms as "rat," "cat," "mask" and even "fish."

Most subjects pointed out that in viewing the display and trying to get an idea of what is going on, there is no time to "register" names of parts as well as actions. In fact, some subjects objected that the technical terminology tends to confuse, e.g., "The names baffled me and put me off." The conclusion that little emphasis should be put on terminology where the chief aim of the display is to convey a coherent account of some action or actions is supported by similar conclusions reached in U.S. research to the effect that technical terminology "does not appear to facilitate the learning of an assembly skill and may actually interfere with such learning" (Jaspen, 1950).

The "impact" of pictorial material.

The most obtrusive qualitative feature of the subjects' performances in these experiments was their manifestly constructive nature. There was an almost infinite variability and individuality not only in the actions and movements, but in the very approach adopted by any given subject, so much so that to an outside observer it might occasionally have appeared doubtful whether the performances were based on the same display or indeed on any display at all. With practically all subjects the performance was more clearly related to the actual task than to the display seen. Not by any stretch of imagination could the performances in any of their aspects be characterized simply as reproductions of the movements and actions shown on the screen. This was particularly striking at the more difficult stages of the task, where subjects often suspended action altogether, apparently to improvise some more or less satisfactory response, or where a wrong response or series of wrong responses tended to occur.

The observed constructiveness of performances as a whole and of its component movements and movement patterns suggested that very little reliance was put by subjects in type of recall (whether expressed in words or actions) based on some sort of serial photographic imagery. Verbal reports, too, offered no evidence that —at any rate with adult subjects—such imagery is either expected to occur, relied on, or utilized. May's hypothetical subject (1946) who carried away with him a "mental film" which he later "reviews" and imitates is less hypothetical than imaginary. This is not to say that imagery does not occur; but it seems that what imagery occurs is itself constructive in nature.

These observations in turn suggested that the "impact" of pictorial material during perception is not by any means simple and immediate, if by simple and immediate is meant that faithful copies of pictures are in some way transferred from the display into minds or brains; and it is precisely this idea which underlies many of the claims made for visual-aid instruction. Although it may still be true that the perception of a highly realistic display differs in some respects from the perception of more symbolic displays, the present experiment contained no evidence for the existence of some basic divergence from the general principles held to govern perceptual processes (Vernon, 1952). On the contrary, there was every indication that just as the performances could be described as series of individually constructed responses, so too can the perceptual process during viewing. The adequacy of performance constructs, moreover, appeared to be intimately related to the success or failure of the perceptual constructions, on which the former were almost certainly based.

The constructive perceptual responses seemed to consist in selecting from the display (not necessarily from the pictorial element of the display only) a number of cues to action (i.e., dominant details) and in organizing these within a general framework or setting which itself results from an integration of actually presented data with a schema of past experiences, brought into the viewing situation. For such an integration to occur it is important both, that the data should be adequately presented—adequacy of presentation and fidelity of representation not being synonymous terms—and that the subject should have a fund of appropriate related experiences to draw on. The present experiment provided evidence to show what happens when inadequacies occur either in presentation or in past experiences.

Many subjects complained that the data were inadequately presented, particularly during the more complex stages of the task. These complaints were frequently framed in such terms as: "The general principle is not made clear enough" or" The construction of the window was not clear." Evidently the majority of subjects were not able to relate the series of actions shown in the displays to each other at the more complex stages, where the display gave no indication how they fitted into the general "system" or how they contributed to the overall aim of the task. It seems that only where the series of actions can be referred to the overall aim can the subject face the task with a more or less clear plan of action. As will have been evident from the quantitative analysis, 90 per cent. of all subjects approached the task without a plan sufficiently articulated to permit satisfactory performance at more difficult stages.

As regards adequacy of related past experiences, it has been shown in the quantitative analysis that such past experiences are probably significant variables. This is further borne out by the case of a subject almost entirely lacking in such perceptual-motor schemata. He could not carry out successfully more than two sub-operations of the task. In the subsequent report he stated: "Presuming it's somebody like me, you would need previous knowledge of tools and such things. I have never used tools before. But I remembered the lead at the end of the string, it was rather like a shoe lace. I had had that experience before and in a way anticipated what he was going to do in the film." Significantly, too, he maintained that "looking at the film is too passive," which probably signals the failure of keeping up perceptual responses.

In view of the preceding argument it further seems likely that the 10 per cent. of subjects who performed correctly even at the more complex stages of the task had an inordinately extensive repertoire of related past experiences to draw on, which helped them to provide for themselves a general setting despite inadequate presentation of data in the display.

That the subjects first and foremost aim during the first showing of a display is to construct the data given into a general setting is also borne out by many reports, which are mostly phrased as subjective estimates of the adequacy of achieved settings: "I have gathered the general idea"—"Easy to pick up the general idea" —"I have a rough idea of the main things." The setting, which appeared to form the basis of performance constructions, are apparently not always established consciously, nor do they necessarily operate consciously. This is reflected in such remarks as: "It comes to you as you are doing it." "It sorts itself out as you go."

As regards what we have termed "cues to action," these need not be related, and in most cases do not appear to be related, to the movements and movement patterns portrayed in the display. In fact, subjects reports as well as observations of their performances suggested that little heed is paid to movements and action details, at least where the display is shown for the first time and is not repeated. What seemed more important was the significance, the meaning of movements and actions in relation to the manipulated objects—the effects they achieved. It further seemed that both the number of cues selected and their fitness for use was related to the adequacy of achieved settings.

The nature of the perceptual process during visual-aid viewing is also partly revealed in the rareness with which the serial order of operations shown in the display was followed in actual performances. Not only was there never any suggestion that the subjects were trying to copy deliberately the display order, but the general behaviour of subjects indicated that they felt they could not be expected to attempt this after a single showing.

Finally, it is necessary to qualify the references to the "display" made in the above context. Since the instructional media used in this experiment were in both instances combinations of pictorial material and verbal commentaries, it is obviously impossible to refer the observed effects to the pictorial element only. Although it is impossible to claim this with any certainty on the bases of the present experiments, it seemed that in so far as the instruction conveyed involved relationships, the comprehension of these relationships was not directly imparted by the pictorial element, but rather by the spoken commentary. It seemed that for such comprehension to occur, the relationship must be formulated verbally either by the subject himself or by the commentary. There is little evidence that subjects can do this. This point, which is of great importance, requires further investigation.

Conclusions.

The conclusions that can be drawn from this pilot investigation must not be regarded as anything but tentative at this stage and this applies with even greater force to any generalizations which suggested themselves as a result of the experiments described. Furthermore, it cannot be assumed that the findings can be extended from the tasks studied to all other tasks or to the communication of information not intended for giving instruction in a task-performance. Within its own limitation the present study suggests these points:

The quantative analysis of the performances mediated by the two types of display (film, filmstrip) did not indicate that continuity in pictorial representation or the inclusion of movement representation (film) necessarily produces better result in terms of correct responses. There were no significant differences between the overall scores of the groups of subjects that could be attributed to specific display effects. The analysis of responses at each sub-operation of the task showed that only at one point could increased learning effects be attributed to continuity in the display, while there was no evidence for any advantage due to motion representation; it is, however, possible that any advantages that might have occurred as a result of motion representation were cancelled out by the restricted temporal availability of the film passages at any given point. It is significant that the performances observed were least adequate at those stages of the task, where the actions shown in the display were related to each other in a more complex manner.

This last point, when considered together with the qualitative character of subjects' performances, virtually excludes the notion that subjects based their performances on photographic images or series of such images. Although subjects frequently testified to the occurrence of imagery, as might have been expected, these images were usually fragmentary and certainly bore no point to point relation to the displays. The performances themselves gave the impression of being constructions devised to meet the requirements of the task.

From these observations it was argued that the perceptual processes that occur during display-viewing are also essentially constructive responses which result in the integration of display data with the subjects own related perceptual-motor schemata into settings, and in the extraction of certain dominant details in the form of "cues to action." With reference to the pictorial displays, there was nothing to suggest that these are either stored as memory-images or that they could furnish ready-made meanings. Such meanings are not supplied by the display, but "read into the display" by the perceiver, though the display might in some instances narrow down the range of possible meanings derived.

From the practical point of view a faithful step-by-step and movement-by-movement demonstration of a task by pictures seem extraordinarily unimportant, particularly if it is achieved at the expense of an adequate explanation of how various actions are related to each other, to the object manipulated and to the final aim of the performance. It appears that the subject often can and usually does construct for himself a great number of necessary actions, provided he has grasped certain crucial features, while adding nothing substantial. Moreover, where these crucial features involve relationships, it is likely that the verbal formulation on the commentary rather than the pictorial element contributes to adequate presentation.

All-in-all, fidelity of representation emerges as a misleading notion in the construction of visual aids to present a manual task. It is adequacy of presentation that should be aimed at and adequacy of presentation is not synonymous with fidelity of representation. What constitutes adequacy of presentation in visual aids is a matter for further exploration.

My grateful acknowledgements are due to the Trustees of the Nuffield Foundation for the financial support given this research and to the University of Reading for providing laboratory facilities. I am indebted to Professor R. C. Oldfield, who has sponsored and steered this research from the start and to Dr. M. D. Vernon for help and advice at all stages. I also wish to thank the Director-General of Medical Services, Air Ministry, the Air Officer Commanding F.T.C. and the Officer Commanding H.Q. (Unit) R.T.C., R.A.F., for this kindness in arranging to make subjects available. Of the many others, who through their co-operation are helping this research along special mention must go to Mr. John Shearman of the Film Section, Iraq Petroleum Co., Ltd., and to Miss Mary J. Locke, Technical Information Specialist at the Office of the U.S. Assistant Naval Attaché for Research. Last but not least my thanks are due to Mr. C. W. Murfin for his technical assistance and especially for constructing the dummy sash-window.

REFERENCES

BARTLETT, F. C. (1932). *Remembering*. Cambridge.

JASPEN, N. (1950). Technical Report SDC 269-7-17, Pennsylvania State College Instructional Film Research Program.

MAY, M. A. (1946). The psychology of learning from demonstration films. *J. educ. Psychol.*, **37**, 1-12.

VERNON, M. D. (1952). *A Further Study of Visual Perception*. Cambridge.

ZUCKERMANN, J. V. (1949). Technical Report SDC 269-7-4, Pennsylvania State College Instructional Film Research Program.

AN ILLUSION OF MOVEMENT COMPLEMENTARY TO THE HORIZONTAL–VERTICAL ILLUSION

BY

R. L. REID

(*From Canterbury University College, Christchurch, New Zealand*)

Blindfolded subjects moved a stylus held in the hand over a standard distance of 4·5 ins. in a given direction. They then attempted to move the same distance in a direction at right angles to the first. Eight combinations of movements were investigated. The results reveal an illusion such that the extent of movements to left or right across the body is underestimated, while the extent of movements towards or away from the body in the mid-line is overestimated. The illusion applies to speed as well as extent of movement. Movement up or down in a vertical plane is equivalent to movement towards or away from the body in a horizontal plane.

The interaction of this illusion with the well-known horizontal–vertical illusion of visual perception explains a failure to find any net illusory effect where lines visually displayed in different orientations were matched for length by unseen movements in similar orientations.

Whether the visual and movement illusions simply co-exist or whether they are functionally related is not yet clear.

I

Introduction

It has long been known that observers will match a line of given length displayed vertically with one of greater length displayed horizontally. Effects related to this horizontal–vertical illusion also occur. For example, vertical movement appears faster than objectively equal horizontal movement. Since vertical distances are visually exaggerated this is to be expected.

At first glance it seems curious that human beings should permanently be subject to a distortion of visual extents according to their orientation. Distortion could only impede adaptive functioning. However, the type of environment that might be supposed to have shaped human evolution would not very frequently present the organism with situations like those that arise in the laboratory when the horizontal–vertical illusion is being measured. The procedure requires subjects to compare and make judgements about the relative lengths of two lines. This is highly artificial. The primary function of visual perception must be regarded as determining movement in relation to objects seen. With this point of view in mind an experiment was designed in order to find out what happens when subjects estimate the lengths of lines in different orientations by making matching movements rather than judgments.

The subjects sat 6 ft. away from a matt black surface on which was placed a strip of white celluloid $3 \times \frac{1}{8}$ in. that could be set vertically or horizontally. They provided estimates of its length by drawing lines in corresponding orientations on a pad of paper. A screen prevented them from seeing either their hand movements or reproductions. The line was presented four times in each orientation and on each presentation the subject produced five estimates. To maintain a fresh approach to the problem subjects were led to believe that on each presentation the line would vary in length. They were told that the variation would be so small that they would not detect it visually and should not try to do so, but that their drawings might provide evidence that they could "register" the differences in length correctly.

The results failed to show any systematic effect of orientation of the line. For a group of 15 subjects the mean length of reproductions with line horizontal was

2·40 in., and with line vertical 2·42 in. The difference of 0·02 in. amounts to less than one-third of its standard error ($t = 0{\cdot}28$).

Similar results were obtained whether subjects made their drawings on a horizontal or on a vertical pad of paper, except that variability was increased when the pad was vertical. With the pad horizontal, the vertical line was drawn by making a movement towards or away from the body along the mid-line. Subjects stated that this movement "felt the same as" vertical movement up or down.

Provisional acceptance of these results at their face value led to a direct test for an illusion of hand movement that would counteract the visual horizontal–vertical illusion.

II

Experimental Arrangements

Subjects

Twelve students, eight male and four female, took part in the experiment. All subjects were right handed.

Apparatus

A 12-in. square of thin glass was set in a frame with edges of smooth hard wood. Graph paper was laid beneath the glass so that distances outwards from each corner could be read in inches and tenths. A thin metal stylus was used by subjects in tracing along the edges of the frame.

Procedure

In all trials the subject worked blindfolded sitting at a table with the board lying flat in front of him. The stylus, held in the right hand, was guided to a position 4·5 in. from a corner of the board. The subject traced along the edge from this position until the stylus reached the corner. This established the standard distance. He then moved along the edge at right angles to the original direction and stopped when he judged he had moved the same distance.

Eight combinations of movement were used. They are shown in Figure 1 with arrows indicating direction. Subjects knew in advance which combination was required. The order of performance was varied at random from subject to subject with the restriction that A and B combinations should alternate. Ten trials were carried out by each subject for each of the eight combinations.

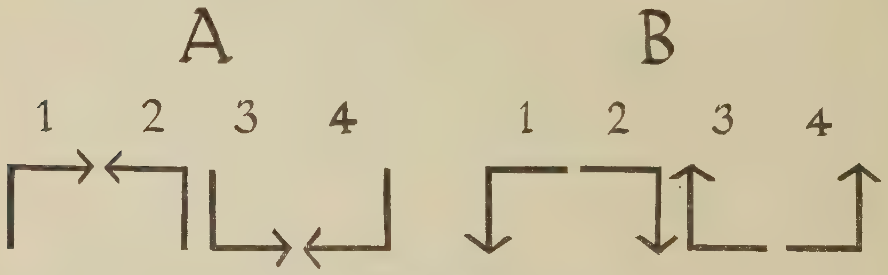


FIGURE 1

Combinations of movement. In all cases movement in the first direction was limited to 4·5 inches.

Subjects were told that the accuracy of hand movement in different directions was being assessed. The procedure was then demonstrated and followed by a number of practice trials that varied according to individual requirements. During both the practice period and the experiment proper, subjects were allowed to see the board only when a new movement was being demonstrated. No guidance was given on methods that might help subjects to make their estimates, but they were told that if they did adopt some method during the practice period they should try not to change during the course of the experiment.

III

RESULTS

Table I shows mean lengths of estimating movements and constant errors for each of the eight combinations. An analysis of variance into three components is given in Table II. The hypothesis that the eight means are drawn from the same population can be confidently rejected. The F-ratio of 15·56 exceeds the value of 5·78 required for significance at the 0·01 level. The difference between pairs of means required for 0·01 significance using the *t*-test is 0·72. Each of the four means for A combinations of movement differs significantly from each of the four means for B combinations. In addition, A4 differs significantly from A1 and A3.

TABLE I

A			*B*		
Movement combination	*Length of estimate*	*Constant error*	*Movement combination*	*Length of estimate*	*Constant error*
1	5·04	+0·54	1	4·24	−0·26
2	5·47	+0·97	2	4·03	−0·47
3	5·24	+0·74	3	4·16	−0·34
4	6·00	+1·50	4	4·20	−0·30
Mean A	5·44		Mean B	4·16	

Standard Movement . . . . 4·50
Geometric Mean of A and B . . 4·75
All entries in inches

The means of the four A and the four B combinations are given in Table I. The geometric mean of these is 4·75 in. showing a general overestimation of the standard amounting to 0·25 in. The geometric mean was calculated since the illusion can be assumed to operate proportionally. Since the standard necessarily came first on all trials this can be regarded as a time error.

TABLE II

Source	*d.f.*	*Sums of squares*	*Variance*
Conditions . .	7	4,570	652·86
Subjects . .	11	2,999	272·64
Residual . .	77	3,170	41·17
Total	95	10,739	

F = 15·86 (7 and 77 d.f.)

Computation from mean estimates of each subject for each combination of movements.

IV

DISCUSSION

No plausible hypothesis can be suggested to account for the significant difference between the mean of A4 and the means of A1 and A3. Otherwise the general pattern of results shows that movements are phenomenally equal when those made to left or right are objectively greater than those made towards or away from the body. An illusion of movement clearly occurs under the conditions as described.

After the end of the experiment subjects were asked to describe the method they had used, if any. As expected, most reports were vague, but seven subjects said that they had tried to keep speed of movement constant while estimating time of moving. Three of these at least carried on continuous subvocal counting. Their results were no different from the results of others who did not mention speed in their reports. Hence there are grounds for believing that apparently equal speeds of hand movement are in fact faster when the movement is to left or right than when it is towards or away from the body. This effect may be similar to one that occurs in vision where horizontal and vertical movement are seen as equal when the horizontal movement is objectively faster. The tendency to increase speed on movement to left or right may have some practical importance.

It should be noted that all movements took place in the horizontal plane. No fundamental difference occurs when measurements are made with the board set vertically in front of the subject. The illusion still holds with vertical up or down movement substituted for outwards or inwards movement. In the experiment described, the horizontal position was used because it provides data of greater reliability than the vertical position. Vertical movement appears to be equivalent phenomenally and as far as illusory effects are concerned to towards and away movement. This is not surprising. In drawing, people seem to find no great difficulty in using a horizontal pad of paper on which they register vertical extents by towards and away movements. On the other hand, making a drawing of a scene representing verticals by lines in any other orientation is awkward. A two-dimensional representation of three-dimensional space involves the projection of depth as vertical separation.

The visual horizontal–vertical illusion may show the same effect in the horizontal as in the vertical plane, but this would be very difficult to check experimentally. With both lines in the horizontal plane and the line of sight horizontal, foreshortening of one of the lines would occur but would be partially masked by constancy effects. The net result would be difficult to predict and the experiment would be trying to subjects who would have to make judgments based on peripheral vision.

The movement illusion results in a figure like that of the horizontal–vertical visual illusion. Knowing the facts of both illusions we can explain the negative result of the experiment described earlier in which visual stimuli were matched by movements. It seems reasonable to postulate that the tendency for a vertical extent visually perceived to be judged greater than a horizontal is counteracted by a tendency for vertical and vertically related movement to appear greater in kinesthetic perception than horizontal movement. To try to elucidate the process, we can think of it like this. If a person looks at a square he sees a rectangle of slightly greater height than breadth (visual illusion). If he attempts to draw such a rectangle blindfold he will produce a square (movement illusion). Thus two illusions cancel each other's effects. Of course, this is a way of explaining the data rather than an attempt to describe any processes that actually occur.

The movement illusion as shown above is greater than the horizontal–vertical illusion would be with an equivalent group of subjects, but against this inequality may be set the fact that through everyday experience subjects may have a little practice in equating lines as seen but are likely to be completely naïve to the task of equating movements.

The visual illusion is loosely named. It has never been shown to have any connection with the horizontal or the vertical in a strict sense. The illusion was measured by the author (*a*) conventionally with subjects sitting upright and (*b*) with the head or the whole body in a horizontal position. A few subjects also made judgments lying on their backs and looking up or lying on their stomachs and looking down. The results showed that the illusion was determined by the orientation of head and eyes to the test figure. There was no indication that the gravitational field or the known horizontal and vertical lines prominent in the room in which the experiment was carried out had acted in any way as determinants of the illusion. The illusory effect was seen to depend entirely on the relationship between eyes and test figure. Provided that the eyes are in their normal relationship with the rest of the body, both visual and movement illusions occur with reference to the same system of co-ordinates.

The ability to make quick accurate movement in response to objects seen has a definite survival value to any organism. Although ordinarily such movement is under visual control yet feed-back processes take time and are best reduced to the minimum. It is tempting to suppose that the two illusions are not merely coexistent but that one is primary and the other a compensatory mechanism that may be established through learning due to its utility. Recently psychologists such as D. O. Hebb have stressed the extent to which learning may enter into apparently simple perceptual processes. Studies of children show that gross errors in reaching out for seen objects occur up to five or six months and suggest that the ability to move accurately in a visual world is established by a long-term process of learning.

Recent work on the visual illusion has not made its basis any clearer. On the one hand, Motokawa (1950) using the electrophosphene effect has provided some evidence that it can be attributed to retinal functioning. On the other hand, a measurement of the illusion by Pollock and Chapanis (1952) at each of the 10-degree positions between 0° (horizontal) through 90° (vertical) to 170° shows that lines tilted to the left of vertical look longer than those tilted to the right. Since the structure of the two retinae is symmetrical and not repetitive these results must be regarded as conflicting with Motokawa's, unless we can believe that judgments of length are based only on the stimulation of one eye.

Experiments in progress are designed to find out whether the visual illusion is derived from the movement illusion. Put in its crudest form, the hypothesis would be that a vertical line looks longer than a horizontal because movement in relation to it would feel longer than horizontal movement. The question is of interest for any light it may throw on the perceptual integration of different sense modalities.

REFERENCES

MOTOKAWA, KOITI (1950). Field of retinal induction and optical illusion. *J. Neurophysiol.*, **13**, 413–426.

POLLOCK, W. T. and CHAPANIS, A. (1952). The apparent length of a line as a function of its inclination. *Quart. J. exp. Psychol.*, **4**, 170–178.

A FURTHER STUDY OF THE PENDULUM PHENOMENON

BY

K. R. L. HALL and A. E. EARLE*

From the Departments of Psychology, Barrow Hospital and University of Bristol.

A first series of experiments had demonstrated certain conditions eliciting or inhibiting a "pendulum" phenomenon in the visual perception of apparent movement. The present study consists of five further variations designed to show more clearly conditions of occurrence and non-occurrence of this type of movement. The main findings are:

(1) Altering the axis of display to vertical significantly reduces the frequency of pendular-movement perception;

(2) Altering the position of metronome from behind to the side of the visual display, gives results almost identical with those where the metronome was inaudible, but, when the metronome is illuminated in this position, all forms of movement perception are reduced, and no pendular movement is reported.

The results for all the ten conditions, including the five of the first series are summarized, and the following possible factors are discussed: past experience, physiological nystagmus, and intervening adaptation. All three may be required to account for the perceptual phenomena under investigation and the dichotomizing of explanations into "experiential," or "physiological," appears to be arbitrary and inconsistent with the complexity of the observed facts.

I

INTRODUCTION

In a previous paper (Hall, Earle and Crookes, 1952), certain conditions for the occurrence or non-occurrence of an arcuate type of apparent movement between two alternating lights were described. With a metronome directly behind the display screen and producing alternating light signals synchronously with the auditory rhythm, the impression of movement of a light along a curved path was very strong. Experimental analysis of some of the conditions facilitating or inhibiting the phenomenon showed it to be complexly determined by, amongst other factors, the circular shape of the lights, their rhythmical presentation, and the warming and cooling of the lamp filaments.

In these experiments it had been noticed that, in addition to affecting the path which the movement seemed to take, certain conditions of stimulus presentation seemed to facilitate the perception of any kind of movement. This general effect was, however, not analysed further because it was only secondary to the main effect on the path of movement, but it appears that Werner and Zietz (1928) had shown intersensory effects which are somewhat similar to this. For example, they used a rate of succession of the visual stimuli which was below the accepted optimum for movement perception, and accompanied this by an auditory rhythm composed of clicks at a rate slightly faster than that of the visual stimuli. Some of their subjects reported definite movements in the visual field. Using an irregular series of taps, however, most subjects experienced a "disintegration" of the visual movement.

There are, then, two closely related problems requiring further experimental investigation. First, the main hypothesis arising from our previous experiments was that the path of seen movement must be primarily determined by a complex interaction of visual display conditions, and secondarily by reference to models derived from past experience. Our results were not conclusive, and it remains for us

---

* In receipt of a grant from the Medical Research Council.

to carry out further variations which may clarify step by step the nature of the original complex pendular phenomenon. Secondly, although we had noticed in our experiments that the total frequency of movement responses of all categories tended to vary in certain conditions, we did not examine this statistically. We shall, therefore, make some appraisal of this "facilitatory" effect in relation to both our present experiments and those we have already reported.

II

METHOD AND PROCEDURE

The subjects were, as previously, doctors, nurses, university students, administrative and laboratory staff, of both sexes, the age range being 20–35, with two subjects above the upper limit. Different subjects were used for each experimental condition, except when transfer effects were being specifically investigated, and only two had any previous knowledge of gestalt perceptual experiments.

The apparatus was identical with that used in the previous experiment, the display unit consisting of two flash-lamp bulbs set on and off alternately by a metronome, the time intervals and exposure times being the same as before to give a total event: Light 1 + Interval + Light 2 = 550 m/s.

For all the conditions of the experiment, the method of presentation and instruction to the subject was identical with that of the first experiments, the observations always being carried out in a darkened room. The subject was required simply to report his impressions, and no indication was given as to what he might expect to see.

III

THE EXPERIMENTS

In our previous investigation, the results of five experimental conditions were reported, and the present series of seven further variations are, therefore, numbered to show continuity and avoid confusion in back reference.

Condition 6.

The display box was set up on end, so that the two lights appeared vertically one above the other, instead of on a horizontal axis as was the case in every other experimental condition. In all other respects—viewing conditions, stimulus-shape, distance between stimuli, timing values, and the audible presence of the metronome—stimulus conditions were identical with those of Condition 1. Ten subjects were used: their reports are summarized in Table V.

TABLE V

FREQUENCY OF FOUR CATEGORIES OF MOVEMENT PERCEPTION FOR TEN SUBJECTS UNDER CONDITION 6

Distance apart in cm.	*Vertical curve*	*Horizontal curve*	*Straight*	*Two-light movement*	*Total movement*	*Total no-movement*
18·5	1	0	2	0	3	7
9·5	1	1	6	0	8	2
6·5	1	3	5	0	9	1
Total	3	4	13	0	20	10

In this Table, as in all the others, the category "Vertical Curve" refers to curved apparent movement between the lights and in the same plane as the surface of the display-screen. "Horizontal Curve" refers to curved apparent movement between the lights and in a plane at right angles to that of the screen. In other words, these categories maintain a constant relationship to the main axis of the display, even though, in the one case of Condition 6, that axis has been changed from horizontal to vertical.

It will be seen that, in comparison with Condition 1, the perception of pendular movement has been drastically reduced, while that of straight movement has been correspondingly increased (comparing frequencies of straight + horizontal curve with vertical movement for the two conditions, $\chi^2 = 22{\cdot}9$, $P = < 0{\cdot}001$). Total movement has also been reduced ($\chi^2 = 6{\cdot}66$, $P = < 0{\cdot}01$).

The shift in movement perception from predominantly pendular in Condition 1 to predominantly straight in Condition 6 may be due to any of three possible factors:

(i) Differences in the organization of complex stimuli in the visual primary projection system according to whether the display axis is horizontal or vertical.

(ii) Differences in facility and track of eye-movements or physiological nystagmus in the horizontal or vertical direction.

(iii) Differences in the likelihood of the hypothetical clock-pendulum model being evoked, explicitly or otherwise, when the display axis is changed to vertical. In this respect, it may be noted that the three "pendulum" reports under this condition were all given by one subject, who spontaneously stated that she was trying to think how the display was being produced, and quickly decided that the underlying mechanism must be a metronome fixed so as to work on its side.

Condition 1 A.

Seven of the subjects of Condition 6 went on to observe the phenomenon under the original Condition 1 (horizontal axis) at the shortest distance between lights. Of these seven, four continued to report straight movement, two reported curved movement on a horizontal plane, and one now reported pendular movement. Thus the general effects of Condition 6 appeared in these subjects to have transferred to Condition 1. This finding is in accord with the effects of experimentally-induced set upon the phenomenon of apparent movement noted by Wertheimer (1912) (quoted by Vernon, 1952, p. 178).

Condition 7.

Comparison of the effects of Condition 1 and Condition 2 indicated that the *audible* presence of the metronome, as distinct from the visual rhythm with which it actuated the lights, tended to increase the frequency and degree (depth of curve) of perceived arcuate movement. In Condition 7, we set out to see what would be the effect of making the metronome not only audible, but also visible to the subject during the period of observation. The metronome was placed clear of the display unit, about three inches to the right of it from the subject's point of view. A screened flashlamp bulb illuminated the metronome with a dim reddish light which was not sufficiently bright to show up any other feature. Electrical connections were such that, as the metronome arm inclined to the left, the left-hand light, and when to the right, the right-hand light came on. Otherwise conditions were identical with Condition 1. The reports of the five subjects who observed under this condition are summarized in Table VI.

TABLE VI

Frequency of Four Categories of Movement Perception for Five Subjects Under Condition 7

Distance apart in cm.	*Vertical curve*	*Horizontal curve*	*Straight*	*Two-light movement*	*Total movement*	*Total no-movement*
18·5	0	0	1	0	1	4
9·5	0	0	2	0	2	3
6·5	0	1	3	0	4	1
Total	0	1	6	0	7	8

The visible presence of the metronome, it seems, leads to a marked reduction in the probability of any kind of movement being seen, and eliminates the pendulum effect altogether. It is possible that this may be a result of the illuminated metronome acting as a distracting element, and causing the observers to keep shifting their region of fixation between it and the screen. As in the other conditions, however, they were told simply to observe what was taking place on the screen, no reference at all being made to the metronome. At any rate, the visible presence of the metronome did not serve to reinforce any hypothetical models of pendular systems which may have been operative in the subject's perceptual processes at the time.

Condition 8.

We noticed that from the observer's position the sound made by the metronome was louder under Condition 7 owing to the fact that the metronome was not screened by the display box. It seemed that this accentuated auditory component might have contributed to the inhibitory effects noted under Condition 7. As a control for this, six subjects observed the display with the metronome in the same position as for Condition 7, but without the metronome being spotlit. When the room light was on the metronome was screened from the subject's view. Thus, apart from the position and loudness of the metronome, the display was identical with that of Condition 1. Table VII shows the distribution of the subjects' reports.

TABLE VII

Frequency of Four Categories of Movement Perception for Six Subjects Under Condition 8

Distance apart in cm.	*Vertical curve*	*Horizontal curve*	*Straight*	*Two-light movement*	*Total movement*	*Total no-movement*
18·5	2	0	1	0	3	3
9·5	3	1	1	0	5	1
6·5	2	0	2	0	4	2
Total	7	1	4	0	12	6

Pendular movement reappears, but with only half the relative frequency observed under the original Condition 1 (the difference is not significant at the 0·05 probability level, χ^2 being 2·03, correction for continuity being applied). Total movement is also significantly reduced ($\chi^2 = 4{\cdot}0$, $P = < 0{\cdot}05$). Why the slightly increased loudness of the coincident metronome beat should exert this inhibitory effect on the phenomenon is not clear, but it is possible that the auditory background in this condition is sufficiently sharp and accentuated to modify the general figure-ground relationship between visual and auditory stimuli which prevails in other conditions.

Condition 9.

One of the most marked effects in the earlier experiments had been the predominance of straight movement in Condition 3, when the lights were square in shape and aligned horizontally on the main axis of the display screen. In Condition 9 we examined the effect of turning the two squares through 45° so that their horizontal diagonals were in line and parallel to the main axis of the display. Otherwise the conditions were identical with those of Condition 3. A résumé of the six subjects' reports appears in Table VIII.

TABLE VIII

Frequency of Four Categories of Movement Perception for Six Subjects Under Condition 9

Distance apart in cm.	*Vertical curve*	*Horizontal curve*	*Straight*	*Two-light movement*	*Total movement*	*Total no-movement*
18·5	2	0	0	0	2	4
9·5	5	0	0	0	5	1
6·5	2	2	2	0	6	0
Total	9	2	2	0	13	5

Compared with Condition 3, the proportion of total movement remains about the same (72 per cent. for Condition 8, and 66 per cent. for Condition 3), but vertical curve rather than straight is now very much the predominant perception ($\chi^2 = 12{\cdot}42$, $P = < 0{\cdot}001$).

Condition 10.

An initial study of the effect of interrupted rhythm was made in Condition 5, when it was found that making the time interval between stimulus 2 and stimulus 1 longer than the standard time-interval between stimulus 1 and stimulus 2, tended to reduce the perception of vertical-curve in favour of straight and horizontally-curved movement. There the longer time-intervals had been 1·5 seconds and 3 seconds. Ten subjects observed at both intervals and at two distances between lights (9·5 and 6·5 cm.). In Condition 10, five subjects observed the display at the three usual inter-light distances and with the longer time interval constant at 6 seconds. As in Condition 5, the lights were actuated by a cam arrangement. The distribution of Group 10's reports appears in Table IX.

This group provides the smallest proportion of total movement responses of any in the whole series of experimental conditions. What movement is observed is straight.

TABLE IX

Frequency of Four Categories of Movement Perception for Five Subjects Under Condition 10

Distance apart in cm.	*Vertical curve*	*Horizontal curve*	*Straight*	*Two-light movement*	*Total movement*	*Total no-movement*
18·5	0	0	1	0	1	4
9·5	0	0	0	0	0	5
6·5	0	0	1	0	1	4
Total	0	0	2	0	2	13

At the bottom of Table X, in which a summary is made of observer's reports for all the main experimental variations, the data derived from Conditions 5 and 10 are arranged in such a way as to make the two groups' reports more directly comparable. Group 10's reports at the 18·5 cm. distance between lights are eliminated. The distribution of the remaining reports is tabulated in three rows, one row for each time-interval between pairs of lights (1·5, 3 and 6 seconds) irrespective of distance between lights.

Condition 11.

An attempt was made to examine the effects of fatigue as a possible factor in the phenomenon. Five subjects were observed under conditions equivalent to those of Condition 1 at the shortest inter-light distance. They continued to report for a period of fifteen minutes, speaking into a microphone which was coupled to a wire-recorder. The record was transcribed and analysed to see if the different types of movement perception appeared in any particular order, or were distributed in any particular way through the period of observation. No systematic tendency could be detected, there being neither any evidence for more rapid change from one type of movement-perception to another during the test period, nor for either straight or curved movement to appear first in sequence.

IV

Summary of Results

A summary of all subjects' reports, except those of Condition 11 (fatigue effect) and the "check" Condition 1A is presented in Table X.

In order to simplify tabulation, the factor of inter-light distance has been ignored, and the figures for each condition refer to the total incidence of particular movement-categories for all distances within that condition. The number of reports falling into each movement-category within any condition is expressed as a percentage of the total number of reports for that condition. Under the heading "Summary of Conditions," the variation from Condition 1 is in each case italicized in order to simplify reference to the Table. The movement-categories are those which have been used throughout the series of experiments.

In considering the "interrupted rhythm" conditions (5A, 5B and 10), it should be noted that the same subjects were used for both parts of Condition 5, while the subjects of Condition 10 had seen the display with the 18·5 cm. inter-light distance, though their reports on this, for reasons explained earlier, are not here included.

For Condition 6, as throughout the Table, "Vertical curve" means a curved path of movement seen in the same plane as the display screen. "Horizontal curve" means a curved path of movement in a plane at right angles to that of the display screen.

TABLE X

Summary of Results.

Frequency of Four Categories of Movement Perception, Expressed as Percentage of Total

	Summary of conditions	*No. of Ss*	*Vert. curve*	*Horiz. curve*	*Straight*	*Two-light*	*Total movement*	*Total no-movement*
1.	Circular, audible, met. not visible behind display, 3 dists. apart.	10	77	0	13	3	93	7
3.	*Square*, rest as for 1.	10	3	0	64	10	77	23
9.	*Diamond*, rest as for 1.	6	50	11	11	0	72	28
2.	*Inaudible*, rest as for 1.	10	40	7	20	3	70	30
7.	*Met. visible at side of display*, rest as for 1.	5	0	7	40	0	47	53
8.	*Met. at side of display: not visible*, rest as for 1.	6	39	6	22	0	67	33
6.	*Axis of display vertical*, rest as for 1.	10	10	13	44	0	67	33
4.	*Neon lights*, 1 dist. apart, rest as for 1.	11	45	0	55	0	100	0
5(A).	*Interrupted rhythm* (1·5 *sec.*), 2 dists. apart, cams for met.	10	15	10	30	0	55	45
5(B).	*Interrupted rhythm* (3 *sec.*), rest as for 5A.	Same as for 5A	5	35	25	0	65	35
10.	*Interrupted rhythm* (6 *sec.*), rest as for 5A.	5	0	0	10	0	10	90

V

Discussion

Two main points emerge from our second group of experiments when these are considered together with the results previously reported by us. The first, and subsidiary, point is the very wide range of variation in the total number of movement perceptions of any kind observed under different experimental conditions. The second point is that with which we have been primarily concerned, namely the factors affecting the path which the apparent movement is taking.

1. *Facilitation and inhibition of apparent movement.*

In the main experimental conditions, where three inter-light distances were used, the range of variation of total movement, expressed as a percentage of the total number of possible responses, is from 93 in Condition 1, to 47 in Condition 7. In other conditions, where only one, or two, inter-light distances were used, the range is from 100 in Condition 4 to 10 in Condition 10. The results for Condition 1 seem to indicate a definite facilitation in the perception of movement of any kind, as, even in comparison with Condition 2, where the metronome was inaudible to the subjects but where otherwise the experimental situation was identical, the proportion of total movement is significantly higher ($\chi^2 = 5{\cdot}45$, $P = < 0{\cdot}02$).

This seems to confirm Werner and Zietz's (op. cit.) finding of a facilitation of movement perception under certain conditions of auditory accompaniment, while our two additional findings with Condition 7 (metronome visible and audible, at side of display) and Condition 8 (metronome audible but not visible, at side of display) indicate that an accentuation of the background stimuli, visually or auditorily, or both in conjunction, can result in a relative inhibition of movement perception. The common factor for these two conditions would seem to be the displacement of the metronome to the side of the display screen, thus perhaps dissociating the auditory rhythm from the visual stimuli. Particularly in Condition 7, the actual showing of the metronome in action to the side might reasonably be considered to have "broken-up" the strong movement pattern of the original Condition 1.

Explanation of these effects is clearly closely bound up with the factors producing the pendulum phenomenon itself, particularly the factor of past experience, and we shall leave further discussion of this to the following section.

2. *The arcuate path of apparent movement.*

The second main point apparent from the summary of results in Table X is the difference in the quality of the perceived movement within experimental conditions which have resulted in an almost identical proportion of total movement responses. Thus, the percentage of total movement in Conditions 2, 3, 6, 7 and 8 varies only from 67 to 77, but the percentage of vertical curve responses varies from 3 in Condition 3 to 50 in Condition 7. The range of vertical curve for all the main conditions is from 0 in Condition 10 to 77 in Condition 1.

We shall now consider in detail three possible factors which, either separately or in combination, may account for these differences in the path of movement.

(1) *Past experience.*

Evidence supporting the effects of experience on the perception of apparent movement may be, for our purposes, classified into two kinds:

(*a*) Expectancy, and familiarity with the content of the display—for example, Piéron's (1934) experiments, using realistic objects familiarly expected to move, and Wertheimer's (op. cit.) study of experimentally-induced set.

(*b*) Cortical elimination experiments, such as those of Smith (1948) and others, where the images of the two stimulus objects are supposed to be separately projected so that such movement as is seen is the product of part-movements, retinally produced, and a central interpretation given to them.

In our first experiment, it seemed possible to us that past experience might be acting to modify the path of apparent movement owing to certain conditions of the display. The display used in Condition 1 had a number of elements somewhat similar to the stimulus-pattern of a mechanical pendulum system, particularly a clock pendulum. A bright disc appeared to move from side to side, in a regular, rhythmical fashion, accompanied by the audible ticking of a metronome. It seemed possible therefore that memory traces derived from everyday experience of clock pendula were being activated by these conditions, and were in some way serving as a background to the observer's immediate perceptual responses. Such a background may be adduced either as the result of a deliberate "effort after meaning," or as the result of a much less explicit matching process. Whichever were the case, the effect might be to modify the movement perception to conform to that which a real pendulum would be expected to take.

If this "experiential" hypothesis is correct, then it should follow that the greater the resemblance of the display conditions to the stimulus pattern of a clock pendulum in oscillation, the greater will be the likelihood of perceived movement taking a pendular form. Reference to Table X shows how far this is borne out by the experimental data. In Condition 1, the resemblance of the stimulus conditions to that of an actual clock-pendulum is certainly greatest, with the regular rhythm, audible metronome etc. It is in this condition that the incidence of "vertical curve" (i.e. pendular) movement is greatest. All other experimental conditions involve a diminution in the degree of resemblance to an actual clock pendulum. For instance, in Condition 2 there is no audible ticking, in Conditions 3 and 9 the lights are square, in Conditions 5 and 10 the rhythm is irregular, and in Condition 6 the axis of display is vertical. Under all these other conditions, a reduction in pendular movement perception takes place in comparison with Condition 1.

Regarded in this way, the data may be said to provide some evidence in favour of the experiential model hypothesis. Further confirmation comes from subjects' reports, which frequently imply the operation of a background model, and from the fact that, when subjects observe two different experimental conditions consecutively, they tend to persist in reporting their initial type of movement perception under the second condition, whereas new subjects would report a different type of movement.

The "model" hypothesis fails, however, to explain the following facts:

(i) Condition 9 (square lights at 45°) produces far more pendular movement than Condition 3 (square lights parallel to the main axis of display), although it could hardly be said that one condition approximated more closely to the real model than did the other.

(ii) The occurrence of horizontally-curved movement.

(iii) The inhibitory effect of neon lamps (Condition 4).

(2) *Physiological nystagmus.*

Two types of experimental evidence have been brought forward in previous work to disprove the hypothesis that following eye-movements play an important part in the perception of apparent movement. These are:

(*a*) Cine-photography gives no evidence of eye-movements consistently following the stimuli.

(*b*) Apparent movement can be perceived in two opposite directions at once.

Objections on these grounds are justly applied in respect of coarse following and fixating movements of the eye, but it seems possible that the much finer and more rapid trembling movements classified as physiological nystagmus may at least contribute to the directing of the path of apparent movement in our own experiments.

The movements comprising "physiological nystagmus" are described as being continuous, oscillatory and involuntary (Duke-Elder, 1932), and they are said to occur with such rapidity and fineness that they may be undetectable by ordinary cine-camera techniques. It would therefore be possible for several nystagmic movements to occur in each direction in the time-interval between the two stimuli of an apparent movement display such as we have used.

The relevance of this hypothesis as a part-explanation of arcuate movement may be understood from the fact that Duke-Elder (op. cit.) and De Jong (1946) distinguish two kinds of nystagmic movements. These are:

(i) Jerky nystagmus, in which a slow movement in one direction is followed by a rapid return to the original position;

(ii) Pendular nystagmus, in which the movements from side to side are smooth, undulatory, and of equal speed in either direction.

According to Duke-Elder, a type of pendular nystagmus is found in children reared in dark surroundings, and can normally be seen in the cat when illumination is dim.

It seems possible, therefore, to the present writers that two features of our experimental situation, namely the regularity of the rhythm with which the stimuli appeared in most conditions, and the low level of general illumination, may have been conducive to the occurrence of a pendular nystagmus, and may have contributed to the perception of pendular apparent movement. Such a hypothesis is supported by the fact that, where the rhythm was irregular (Conditions 5 and 10), pendular movement was relatively rare. It fails, however, to explain why a regular rhythm should not have induced much arcuate movement when the stimulus lights were square.

(3) *Intervening adaptation.*

We have seen that neither of the two factors so far discussed have been adequate to account for all the facts in our two series of experiments. It is proposed, therefore, to review a third explanation derived from the so-called "statistical" theory of visual acuity as propounded by Marshall and Talbot (1942) and applied to the explanation of figural after-effects by Osgood and Heyer (1952). Such a theory seems in many ways preferable to the Gestalt conceptions of "physiological short-circuits," leakage of excitation across the cortex, and the operation of extra-neural field-forces.

Marshall and Talbot drew attention to certain physiological mechanisms whereby a pattern of visual stimuli can become both spatially extended and temporally prolonged on its route from the retina to the visual cortex. These mechanisms include diffraction in the pupil, physiological nystagmus, reverberatory activity, multiplication of unit pathways, and reciprocal overlap. The authors conclude that the cortical representation of a contour is probably a normal distribution of excitation symmetrical about its axis. If this is correct, it would follow that the cortical representation of the stimulus shapes used in our experiments would consist of a region of relatively intense and homogeneous excitation surrounded by a region in which the intensity of excitation falls off towards the periphery. Thus the two stimuli will be represented by two foci of activity in the cortex which have no clear-cut boundaries. Under certain conditions of stimulation, considerable summation might be expected to take place in the region between the two foci, and this could furnish the excitatory basis for the perceived path of apparent movement.

Such an account would lead one to expect the apparent movement to take place always along the most direct path between the two stimuli, but it seems possible to extend the implications of the statistical theory to our own pendulum phenomenon by bringing in the factor of satiation or adaptation. Sanders (1921) is reported by Bender and Teuber (1946) to have shown that prolonged stimulation of a retinal area inhibits stroboscopic motion across it. Detherage and Bitterman (1952) made a similar observation, and also noted that, when the two stimuli of an apparent movement display are placed slightly to one side of an area occupied immediately beforehand by a circular inspection-figure, the path of apparent motion is reported as being curved concentrically with the previously displayed circle.

These observations no doubt arise from a set of underlying cortical processes similar to those producing figural after-effects in general. They are important to our experiments because they suggest one possible condition within the visual projection system—i.e. a region of localized adaptation between the two postulated foci of excitation—which might account for the deviations in the path of apparent movement reported in some of our experimental situations.

A possible explanation in terms of such an "intervening adaptation" is outlined below, and is schematically represented in Figure 1, where the three different light-shapes used in our experiments are shown.

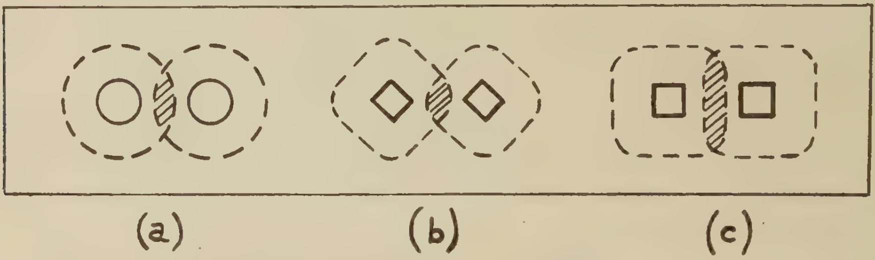


FIG. 1. Diagram of hypothetical regions of adaptation for three different light-shapes.

In Figure 1, the inner figures (solid lines) represent the supposed spatial arrangement in the visual cortex of the two foci of excitation. The area between these foci and the outer broken lines represents a region in which some peripheral excitation might be expected to occur. Where the two peripheral regions overlap (shaded area), some summation of activity from either focus should take place. Considering a single pair of stimuli, or recurrent pairs separated by an appreciable interval of time, the path of apparent movement ought to be straight, since the region of greatest summation would be that directly intermediate between the two foci.

Where the rhythm of presentation is regular, however, the situation may be altered, since repeated excitation of the region of overlap from foci on either side of it will mean that cells in this region are firing in bursts which occur twice as frequently as those in either focus considered by itself. Given a critical relationship between stimulus-frequency and recovery-cycle, this may cause the region of overlap to become progressively adapted, so that after a number of exposures the cells in this region will cease to respond to stimulation. A gradient of relatively more intense excitation would then be created round the periphery of the region of overlap, and this gradient might then form an excitatory basis for the path of apparent movement.

Such an account would seem to fit the three situations represented in Figure 1. In (*a*) the region of peripheral overlap is fairly compact and circumscribed. This is even more the case in (*b*) with the diamond-shaped lights, but in (*c*) the region of overlap is narrow and elongated. As the region of adaptation corresponds to the region of overlap, this seems to offer a reasonable explanation for the fact that the highest proportions of arcuate movement are reported in Conditions 1 and 9 (77 and 61 per cent. respectively), as against 3 per cent. in Condition 3 where the stimuli were square; square stimuli, tending to produce a long and narrow region of adaptation, should lead to the perception of straight movement with the middle part of the path being seen as indistinct.

It can be seen, therefore, that this intervening adaptation hypothesis may adequately account for the following facts:

(1) The greater incidence of curved movement when the interval between pairs of stimuli is reduced (less recovery from adaptation being possible).
(2) The greater incidence of curved movement when the distance between stimuli is reduced (the region of peripheral overlap being greater).
(3) The greater incidence of curved movement when the lights are circular or diamond-shaped, as compared with that observed with square lights.

It does not, however, explain why altering the axis of display from horizontal to vertical should so reduce pendular movement, and it fails to account for certain minor variations, such as the effects of making the metronome inaudible, using neon lights, transfer situations, and so on. On the basis of such a theory also, it might have been predicted that, when the original display situation with circular lights, etc., was presented continuously for about 15 minutes (Condition 11), perception of movement would begin as straight, then change to pendular, and remain fairly consistently pendular thereafter. Our evidence under this Condition is not at all conclusive, and this situation might well be repeated. Finally, it is difficult to understand, on the adaptation hypothesis alone, why the curve should have generally been reported as dipping rather than arching.

CONCLUSIONS

We emphasized initially that no single explanation, but a combination of explanations, might be required to account for the various apparent movement phenomena observed in our experiments. This was to be expected from reviews of visual apparent movement experiments such as that of Neff (1936), whose conclusion was: "Of the twenty or more significant variables which have now received treatment, we can simply make the general statement that any or all of them, in a large number of possible forms of combination, may suffice to bring about a perception of movement" (p. 37).

Our conclusion must be that each of the three hypotheses we have discussed is necessary to explain one or more of the sets of observations in our experiments. It seems reasonable to suppose that the hypothesis of intervening adaptation can account primarily for the effects of light-shape variation under conditions of rhythmical presentation. By itself, however, it does not account for the difference brought about by presenting the circular lights on a vertical axis. Here, Osgood and Heyer's (op. cit.) account of the contributory effect of physiological nystagmus may be directly relevant, for they point out that: "Owing to the manner in which the ocular muscles are attached and balanced (and probably also to some extent owing to experience), these fine eye movements are more extensive in the horizontal than in the vertical plane" (p. 110). This provides a further link between physiological and experiential explanations, and may also account for the fact that, usually, pendular movement is perceived as dipping down and not arching over the horizontal axis of display.

Finally, there is little doubt that experience of certain familiar models, such as clocks, pendula, etc., may be a contributory factor, where the conditions of stimulations are, as it were, finely balanced between the possible perception of one form of movement and another. Further, as Osgood and Heyer point out, the way in which physiological nystagmus takes place may be partly a product of experience. Our results, however, could certainly not support an uncompromising experiential theory such as Piéron's (1934, 1952), where he states that, if physiological systems intervene in movement perception, they do so only in so far as they have been ". . . modelled by the repetition of perceptual experiences along the lines of associative mechanisms revealed by the study of conditioned reflexes" (1934, p. 226).

References

De Jong, R. N. (1946). Nystagmus: an appraisal and a classification. *Arch. Neurol. Psychiat.*, **55**, 43–56.

Detherage, B. H., and Bitterman, M. E. (1952). The effect of satiation on stroboscopic movement. *Amer. J. Psychol.*, **65**, 109–18.

Duke-Elder, W. S. (1932). *Text Book of Ophthalmology*, Vol. 1, London.

Hall, K. R. L., Earle, A. E., and Crookes, T. G. (1952). A pendulum phenomenon in the visual perception of apparent movement. *Quart. J. exp. Psychol.*, **4**, 109–20.

Marshall, W. H., and Talbot, S. A. (1942). Recent evidence for neural mechanisms in vision leading to a general theory of sensory acuity. In: H. Klüver, ed. Visual mechanisms. *Biol. Sympos.*, **7**, 117–64.

Neff, W. S. (1936). A critical investigation of the visual apprehension of movement. *Amer. J. Psychol.*, **48**, 1–42.

Osgood, C. E., and Heyer, A. W. (1952). A new interpretation of figural after-effects. *Psychol. Rev.*, **59**, 98–118.

Piéron, H. (1934). Remarques sur la perception du mouvement apparent. *Année Psychol.*, **34**, 245–48.

Piéron, H. (1952). *The Sensations*. London.

Sanders, E H (1921) Nederl. tijschr. v. geneesk., 65, 1820–1836: quoted by Bender, M. B., and Teuber, H. L. (1946). *Arch. Neurol. Psychiat.*, **55**, 627–58.

Smith, K. R. (1948). Visual apparent movement in the absence of neural interaction. *Amer. J. Psychol.*, **61**, 73–8.

Vernon, M. D. (1952). *A Further Study of Visual Perception*. Cambridge.

Werner, H., and Zietz, K. (1928). Über die dynamische struktur der Bewegung. *Zsch. f. Psychol.*, **105**, 226–49.

Wertheimer, M. (1912). Experimentelle Studien über das Sehen von Bewegung. *Zsch. f. Psychol.*, **61**, 161–265: quoted by Vernon, M. D. (op cit.).

APPARENT TRANSPARENCY AND THE TUNNEL EFFECT

BY

ALAN J. GLYNN, O.F.M.

From the Laboratory of Experimental Psychology, Louvain.

SUMMARY

Experimental evidence can be adduced to show that when an object passes behind an opaque screen, its form may appear unchanged even though certain of its parts are invisible ("screen effect," "tunnel effect"). It has also been reported that, under certain conditions, the form continuity of the object can be directly seen because the opaque screen appears to be transparent (Rosenbach phenomenon). The aim of the present research was to clarify the relationship between these phenomena.

The experimental method consisted in presenting to the observers a grey rectangular figure (12 cm. × 1·2 cm.), moving across the ground glass of a camera, to which an opaque screen (15 cm. × 1 cm.) of lower brightness was attached.

It was found that the apparent transparency of the screen depended, in part, on the subject's preparation for the task. In addition to the factor of "set" practice was also important.

The analysis of the responses of the observers showed that the form continuity of the figure appeared under three distinct, but related, forms of structural organization: an unshaped darkening on the screen, a shaped darkening on the screen, and transparency. Each type of response could be favoured by an appropriate instruction. Furthermore, any change in the stimulus situation affected them all in the same way.

The other factors conditioning the form continuity of the figure pertained to the stimulus situation. These were the speed of the translation motion of the figure, the dimensions of the figure and the screen, and the brightness relation between them.

The study of the Rosenbach phenomenon showed that it was not related to the "screen effect" and the "tunnel effect."

Il a été démontré expérimentalement que la forme et la grandeur apparentes d'un objet peuvent demeurer inaltérées bien que certaines de ses parties soient invisibles ("effet écran," "effet tunnel"). On a signalé d'autre part que, dans certaines conditions, un écran opaque qui recouvre partiellement un objet peut sembler transparent et qu'on a alors l'impression de voir l'objet dans sa totalité (phénomène de Rosenbach). Le but de la présente étude était de préciser les relations existant entre ces phénomènes.

La méthode expérimentale consistait à montrer aux observateurs l'image d'une figure rectangulaire de teinte grise (12 cm. × 1·2 cm.) projetée sur le verre dépoli d'une chambre photographique et parcourant celui-ci de part en part, tout en croisant un écran opaque plus sombre (15 cm. × 1 cm.) fixé au milieu de la face antérieure du dit verre dépoli.

On a trouvé que la transparence apparente de l'écran dépendait en partie de la préparation du sujet, de son attitude mentale et de l'exercice acquis.

L'analyse des réponses des observateurs a montré que la continuité de la forme de la figure pouvait se présenter de différentes manières: comme obscurcissement local informe de l'écran au moment du passage de la figure; comme obscurcissement de forme définie continuant le contour de la figure; et enfin sous l'aspect de la transparence. Chaque type de réponse peut être favorisé par une instruction appropriée, et, de plus, des changements apportés au système de stimulations les affecte tous dans le même sens.

Les autres facteurs déterminant la continuité apparente de la forme ressortissent au système de stimulations: la vitesse de translation de la figure, ses dimensions et celles de l'écran, et surtout les rapports de brillance des différentes parties du champ.

L'étude du phénomène de Rosenbach a permis d'établir qu'il était d'un autre ordre que "l'effet écran" et que "l'effet tunnel".

I

INTRODUCTION

A series of experiments by Michotte and his collaborators (Sampaio, 1943; Knops, 1947; Michotte, 1950) has shown that if the length of a moving object (e.g. a rectangle) is gradually decreased after it has attained the border of a stationary object (e.g. another rectangle), the former does not appear to the observer as diminishing progressively in size, but as retaining its initial dimensions and "sliding behind" the latter ("screen effect"). Similarly, under appropriate conditions, the movement of an object passing behind a screen may appear absolutely continuous, even though one of its phases is hidden by the screen ("tunnel effect"); *vide* Burke, 1952. Michotte has coined the expression "amodal aspect of perceptual experience," to designate the phenomenal presence of the hidden part of an object or process when there are no sensory modalities corresponding to that part.

Many years ago, Rosenbach (1902) reported that, under experimental conditions more or less similar to those of the "screen effect" and the "tunnel effect," the observers actually saw the form and colour of the parts of an object, through the opaque screen which covered them. That is, in this case, there was a "modal presence" of these parts as the screen seemed to be transparent. The "modal presence" of the covered parts in Rosenbach's experiment and their "amodal presence" in the "screen effect" and "tunnel effect" suggested that the two might differ only in degree and not in kind. If such a continuity could be established, the "amodal presence" of the covered parts in the latter cases could eventually be considered as the lowest limit of the apparent transparency, corresponding to a system of excitation inferior to its threshold. The aim of the present research was to study the conditions of the Rosenbach phenomenon systematically in order to ascertain if such a hypothesis is tenable.

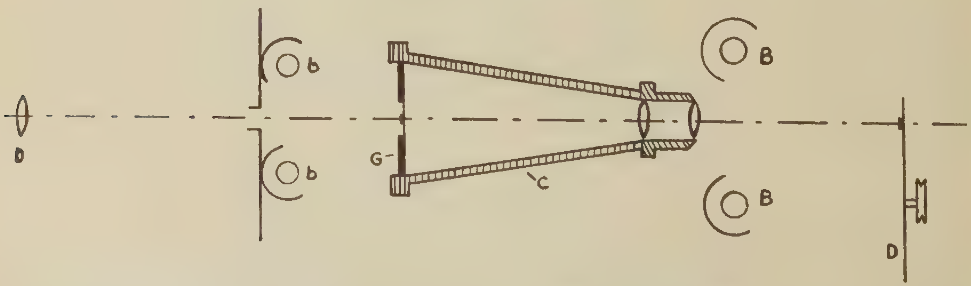
Rosenbach's experimental material consisted of coloured figures of various shapes (triangles, ovals, rectangles), placed behind a narrow band (1 cm.) of black opaque paper in such a way that parts of the figure protruded on either side of it. He instructed his observers to move the figure back and forth beneath the stripe and then asked them if it was transparent. Practically all the observers affirmed that it had to be, since they saw the figure through it. They saw a mixture of the colour of the figure and of the stripe on the crossing-point.

II

Method

The procedure eventually adopted for use in the research, evolved out of a series of preliminary trials in which other conditions were used and then rejected. Our aim was to reproduce as striking an impression of transparency as possible within the framework of Rosenbach's conditions, but in such a way that each factor of the objective situation could be controlled for systematic study. As a result of these trials, two modifications were introduced into Rosenbach's original procedure. The first was the use of a projection device (a photographic camera). This enabled us to eliminate disturbing shadows

FIGURE 1



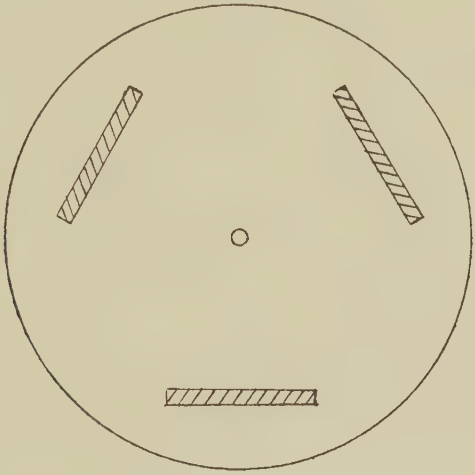
O = Observer. b = Small bulbs. G = Ground glass with shades and, in the middle, the opaque screen. C = Photographic camera. B = Large bulbs. D = Rotating disc.

cast by the screen on the background when the situation was viewed directly. In addition, it allowed systematic and controlled variations of all sorts. The second modification was the limitation of the study to achromatic material.

A schematic drawing of the experimental arrangement as it was set up in the dark room of the laboratory appears in Figure 1. The subject viewed the ground glass of the camera through an opening (5·7 cm. × 6·5 cm.) in the black screen, with his head firmly fixed in the headrest. A vertical stripe (15 cm. × 1 cm.) of opaque paper, placed at the centre of the ground glass, served as the screen. Two adjustable flaps limited the visible area of the ground glass on either side of it to 1·5 cm. This distance between the border of the screen and the border of the flaps was kept constant even when wider screens were placed on the ground glass. The two small bulbs, attached to the reverse side of the observer's screen, provided an illumination on the screen and the ground glass.

A disc of white cardboard, bearing three grey rectangular figures set tangentially to its centre, rotated at a constant speed in front of the camera. (Fig. 2.)

FIGURE 2



The image which the disc projected on the ground glass, was that of a rectangle (11 cm. × 1 cm.) on a white background, moving uniformly (linear speed: 18 cm. per sec.) in an arc of a circle across the field. At the point of its trajectory where the figure lay across the middle of the screen, it appeared to the observer to pivot suddenly about an apparent horizontal axis, that is, about an axis perpendicular to the surface of the screen. (Fig. 3.)

The standard conditions of brightness of the opaque screen, figure, and background were as follows:

The reflection factor of the "normal" opaque screen amounted to 0·34, and its illumination provided by the small bulbs was ± 35 Lux.

Taking this brightness as unity, the relative brightness of the moving rectangle (figure) was 1·6 and that of the white background 2·2, the transmitted light through the ground glass and the reflected light on its surface being both taken into account.

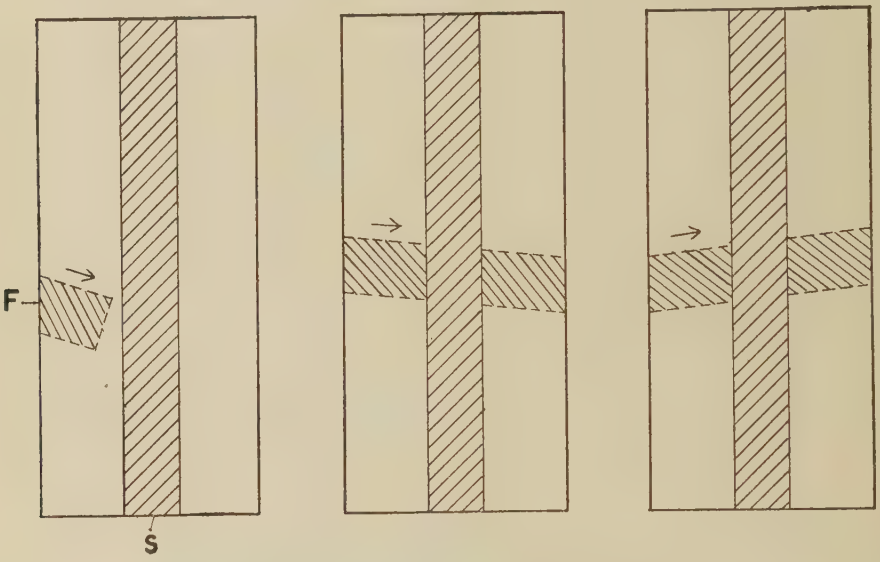
This method was used throughout the experiments except where a change in the experimental procedure is explicitly indicated.

III

The Preparation of the Subject

In his study of the "tunnel effect," Burke, 1952, found that it was sufficient to ask untrained observers what they saw in order to obtain an accurate description of the movement of the object, its continuity, discontinuity, etc. It soon became clear that, even under our optimum physical conditions, a neutral instruction was insufficient to obtain a report on the phenomenon which we intended to study. In an experiment with such an instruction under standard conditions, only 2 subjects in a group of 25 untrained subjects reported that, on one of the three presentations of the figure passing the screen, they thought they saw a shadow on it at the crossing-point. The other 23 subjects limited themselves to a detailed account of the appearance of the figure, the course of its lateral movement across the ground glass, and the character of its swinging movement as it passed the screen. The subjects were then given three more presentations and asked two further questions: whether a part of the figure was hidden by the screen at the crossing-point and how they would describe the screen in relation to their response. Twelve subjects (48 per cent.) reported seeing the figure as continuous in form, 9 subjects (36 per cent.) saw it as hidden by the screen (i.e. as a simple "tunnel effect"), and 4 subjects (16 per cent.) spoke of a "shadow" at the point of crossing. Of the 12 subjects who reported the figure as continuous, only 1 subject referred to the screen as "vaguely transparent." With repeated trials, all save 2 of the 25 subjects reported that the rectangle was uninterrupted in form as it passed the screen. Only 15 subjects, however, described the screen as transparent. The remaining 8 subjects reported that the screen was not transparent, but appeared to be darkened on the area where the rectangle passed behind it.

FIGURE 3



S = Opaque screen placed on the ground glass.
F = Figure (moving rectangle)

(both screen and figure were under standard conditions plain greys of different brightness—see text)

Two other systematic experiments were undertaken to clarify certain results of this initial experiment. The first of these was devised to determine the role of practice on the report of figural continuity under an instruction to note whether the contours of the figure were continuous or interrupted by the screen. Sixteen untrained subjects took part in this experiment. The second experiment compared the responses of thirty untrained subjects under two different instructions. Approximately half of the group were asked first about a brightness change on the screen and then about its transparency. The rest of the group reported first on the transparency of the screen and then on the brightness change. Both experiments were carried out under standard conditions except for the screen which was only 30 mm. high. The responses of the subjects were recorded after each of three presentations in the first experiment. In the second experiment, the subjects gave their reports after three presentations.

The observers' reports on these three experiments led to certain significant findings on the influence of "set" and learning on the structural organization of the stimulus field. It is appropriate to state them as general conclusions before the analysis of the objective conditions of the Rosenbach phenomenon, since the latter are only effective if these factors are present.

1. The response of figural continuity was, at least in part, the outcome of a certain "set." Unless the observers were induced, through the instructions, to concentrate their attention on the form completion of the figure, they did not mention this aspect of the field, but reported only on the movement of the figure, its direction, speed and uniformity. The situation thus appeared to them initially as a pure "tunnel effect." Our results indicate that this detail was omitted not because the observers considered it unimportant, but because they did not notice it at all. Even with repeated presentations of the figure passing the screen, there was no spontaneous mention of the contours of the figure as continuous under a neutral instruction. This finding fully substantiated Rosenbach's (1902) claim that the form continuity of the figure was, in part, a function of the instruction which induced the observer to adopt a certain attitude *vis-à-vis* the stimulus field.

2. A second factor helping to elicit the response that the figure was continuous, was that of learning. When the observers were instructed to report whether the contours of the figure were continuous or hidden by the screen, most of them reported only a darkening of ill-defined shape and indefinite localization (a reversal of simultaneous brightness contrast) on a single presentation of the experiment. With additional practice, (two presentations were sufficient for the majority of the subjects in the second experiment), the brightness change assumed both of these characteristics so that the figure was described as continuous in form. The manner in which the darkening was localized divided these responses into types. The first type of response was of a precise darkening *on* the screen. This corresponded exactly to the form of the figure so that its contours were clearly delineated on the screen. The subjects found it extremely difficult to define the material character of the screen in relation to this darkening effect. Either they said that it was not transparent or they replied that they did not know whether it was transparent or not. In the second type of response, the subjects reported that they saw the figure as "dark" *through* the screen. They described the latter as transparent either directly or by an equivalent expression (eventually translucent). The two characteristics which distinguish this type of response from the preceding were: (1) the brightness change as assigned to the figure and located in its place; and (2) there was a phenomenal separation of the retinal stimulation corresponding to the crossing-point so that both figure and screen were represented as having a distinct brightness of their own. This phenomenal dissociation of the retinal stimulation into two components, one of which is appropriated to one object and the other to the second seen through it, is the salient characteristic of the impresssion of transparency.

It is to be noted that, although the observers defined the screen as transparent, they did not report that the covered part of the figure appeared in its true colour. Highly trained observers occasionally gave such reports.

3. Finally, these experiments showed that the three responses, unshaped darkening, shaped darkening, and transparency were related. The latter responses arose as further specifications of the first. A comparison of the frequency of the responses of a shaped darkening and of transparency revealed that, when the experimental situation was presented to the same observers under an instruction equally favourable to each type of response, the first type of figural continuity was more easily attainable than the second.

IV

The Stimulus Pattern

The influence of "set" and learning on the form completion of the figure obviously depended on determined stimulus conditions. This led to a second series of experiments in which the various factors of the visual field were systematically modified in order to determine the optimum physical conditions for the Rosenbach phenomenon. The subjects who took part in these new experiments were 5 members of the laboratory staff (Mi, Mo, Kn, Ge, Gl) and 19 of the 25 subjects who had participated in Experiment 1. Of the laboratory personnel, two (Mo, Ge) consistently saw the continuity of the figure as a shaped darkening on the screen. The three others (Mi, Kn, Gl) generally gave a transparency response, but, under less favourable conditions, located the brightness change on the screen. The 19 subjects were similarly divided on the type of response which they gave: 14 subjects (74 per cent.) described the screen as transparent; the remaining 5 subjects (26 per cent.) located the dark area on the screen. The predominance of transparency responses among the 19 subjects was due undoubtedly to the suggestion given them by the third instruction of the first experiment. Regardless of the particular form of response, the stimulus factors which were conducive or detrimental to seeing the figural completion were the same in both cases.

The form completion as the result of the extension of the contrast relation between figure and background to the screen.

The two types of response which implied the form completion of the figure possessed a common element, a darkening, at the crossing-point of the screen. What was singular about this brightness change was that it was exactly the reverse of the contrast effect which could be expected on the area of the screen lying between the projecting parts of the figure. Instead of making this area of the screen brighter than its other parts, the projecting parts of the figure acted in the opposite sense. Two experiments were performed to determine what this inverse induction represented.

In the first of these experiments (Experiment 4) a black background (relative brightness 0·6—see page 127) was substituted for the usual white background of the standard figure. The four members of the staff (Mi, Kn, Ge, Gl), who served as subjects, were given several presentations of the experimental situation. All the subjects reported that the completion now appeared as a well-defined bright area and not as a dark area. A similar brightness reversal took place on the parts of the screen adjacent to the crossing point: they appeared darker than the critical area while, under standard conditions, they were always reported as brighter than it.

The reports of this experiment led to the conclusion that the primitive fact in the form completion of the figure was the maintenance of the contrast relation between the figure and the background across the screen.

The second experiment (Experiment 5) was designed to test this conclusion by the simple expedient of suppressing the surface contrast relation and noting its effect on the form continuity of the figure. Mere outlines of the rectangular figures, drawn with black ink on white backgrounds, were presented to four members of the staff. Only 1 subject (Ge) reported the contours of the rectangle as continuous on the first trial after several presentations. Another subject (Mi), who had tried many times previously without success, saw the designed figure as continuous after the first subject (Ge) reported, in his presence, the contours as faintly continuous. The third subject (Kn) saw no continuity on his first trial after more than twenty presentations. On the following day after an equivalent number of presentations, he finally had some impression of continuity. The final subject (Mo) never reported the contours of the figure as continuous on three trials made on three successive days.

The data derived from these two experiments completed one another: the first links the change on the screen to the contrast between the brightness of the surface of the figure and that of the background; the second shows that once this factor is suppressed, the figural continuity practically disappears. The apparent change on the screen may thus be described as an extension of the contrast situation existing between the figure and the background to the screen, or as a mixture of the screen's brightness both with the brightness of the figure and that of the background. In his account of the phenomenon, Rosenbach only considered the mixture between the figure and the screen. These experiments show that a brightness change takes place not only at the crossing-point, but also on the parts of the screen immediately adjacent to it. This area, which extends a few mm. above and below the crossing-point, appears brighter than it with figures set on white backgrounds and darker than it with figures set on black backgrounds.

The influence of the brightness relation between the figure and the screen.

Under optimum stimulus conditions, there was only a slight brightness difference (low contrast) between the figures and the screen. A systematic experiment was designed to study the degree of contrast difference consistent with the form continuity of the figure.

Experiment 6.

Experimental conditions.—The figure was the standard gray. Four screens of different brightness, with a reflection factor of 0·75, 0·34 0·19 and 0·04 respectively, were presented on the ground glass in pairs. The visible area of the ground glass was increased to 10 cm. in width and the screens placed 2 cm. from its centre on either side.

Subjects and procedure.—The subjects were 19 of those who had previously served in Experiment 1. Two screens of different brightnesses were shown simultaneously on the ground glass. The screens were then removed and replaced by two others until each screen had been compared with all the others. Each subject made two such comparisons for each combination of screens. This order as well as that of the position of the brighter screen on the ground glass, was reversed in the second series. The experimenter instructed the subjects to look first at the screen on the right side of the ground glass and then at the one on the left. Two presentations were given for each screen. The subject was asked to report whether the figure was continuous in both cases and which screen gave the better impression of continuity.

Results.

Table I summarizes the results of this experiment. A chi-square analysis (expected frequencies for all brightnesses: (321) (114/456) shows that the frequencies are significantly different ($\chi^2 = 53{\cdot}5$) at the 0·001 per cent. level for 3 d.f.

TABLE I

FREQUENCIES OF FORM COMPLETION RESPONSES WITH INCREASING BRIGHTNESS DIFFERENCES BETWEEN FIGURE AND SCREEN

*Screen brightness**	*N*	*Absolute frequency*	*Per cent.*
0·75	114	24	21
0·34	114	106	93
0·19	114	96	84
0·04	114	95	83
	456	321	

* Factors of reflection.

If the brightest screen is excluded from the Table, the χ^2 is equal to 0·6 which is not significant for 2 d.f. The reason for the difference in the two cases is evidently connected with the brightness relation between the figure and the screen. The white screen appeared much brighter than the figure. With all the other screens, the brightness gradient went in the opposite direction: the screen always appeared darker than the figure. Where this relation was observed, there were no significant differences in the frequencies of the completion responses. Thus screens of 0·19 and 0·04 brightness were also consistent with figural continuity. The completion, however, was not of equal impressiveness. The standard screen was the most favourable for that response. The white screen, on the other hand, was most unfavourable. The loss of figural continuity with this screen may have been due to a strong contrast effect between the figure and the screen counteracting the opposite induction (darkening).

TABLE II

Relative Frequencies with which the Screen Given at the Top was Preferred to those at the Left

*Screen**	0·75	0·34	0·19	0·04
0·75	—	0·87	0·74	0·71
0·34	0·05	—	0·26	0·21
0·19	0·05	0·63	—	0·87
0·04	0·13	0·68	0·53	—

* Factors of reflection.

A second method for studying the need of a determined direction of the brightness gradient between figure and screen was to leave the screen constant and vary the brightness of the figure.

Experiment 7.

Experimental conditions.—Figures of four different brightnesses (see Table III) were shown on white backgrounds. As they appeared on the ground glass, the first two were brighter than the standard screen, the last two darker.

Subjects and procedure Five members of the staff (Mi, Mo, Kn, Ge, Gl) served as subjects. Two presentations of the different figures were given. Four observations were made by each subject on different days beginning alternately with the two extremes of brightness.

Results.

The results of Experiment 7 are given in Table III. No statistical analysis is needed to reveal the detrimental effect of changing the direction of the brightness gradient in the case of figures of different brightnesses seen on white backgrounds.

TABLE III

Frequencies of Form Completion Responses with Increasing Brightness Differences between the Figure and the Standard Screen

*Figural brightness**	*N*	*Absolute frequency*	*Per cent.*
1·6	20	20	100
1·25	20	20	100
0·8	20	2	10
0·6	20	0	0

* Relative brightness values. See p. 127.

As a further check on the influence of the direction of the brightness gradient between figure and screen, the 0·6 figure on a white background was tested with a black screen (Experiment 8). This restored the proper brightness relation. The three subjects (Mi, Ge, Gl) unhesitatingly reported the figure as completed on the first trial. This excluded the possibility of ascribing the negative results with this figure in Experiment 7 to the brightness difference between the figure and the background.

The same subjects served in an additional experiment with the figures of different brightnesses on *black* backgrounds. Its purpose was to determine whether the figural completion demanded a brightness gradient which was the reverse of that required for the same figures seen on white backgrounds (Experiment 9). That is, did the screen have to be brighter than the figure when the latter was presented on a black background? In carrying out this experiment we met with technical difficulties due to the light reflected on the ground glass. For this reason we will limit ourselves to saying that we found some indications that this was the case.

The influence of the width of the screen.

The importance of the brightness value of the screen for the continuity of the figure suggested that its width might also exercise some control on this response. This was investigated in the following experiment.

Experiment 10.

Experimental conditions. Screens of standard brightness with the following widths: 5 mm., 10 mm., 20 mm., 30 mm., 40 mm., 50 mm., and 60 mm. were attached successively to the ground glass.

Subjects and procedure. Five members of the staff (Mi, Mo, Kn, Ge, Gl) served as subjects. Four observations were made by each subject on different days beginning alternately with the screens of smallest and largest width.

Results.

The results are presented in Table IV. No statistical analysis is required to deduce the conclusion that the figural completion can only extend a certain distance.

TABLE IV

FREQUENCIES OF FORM COMPLETION RESPONSES WITH SCREENS OF INCREASING WIDTH

Width of the Screen (mm.)	*N*	*Absolute frequency*	*Per cent.*
5	20	20	100
10	20	20	100
20	20	9	45
30	20	3	15
40	20	0	0
50	20	0	0
60	20	0	0

The influence of the phenomenal appearance of the screen.

Additional properties of the screen were investigated in connection with the fact, discovered early in the research, that a loss in the surface colour appearance of the screen accompanied the form continuity of the figure. If this observation was valid, then any method of preserving the surface colour appearance of the screen should destroy the figural completion. It could easily be tested: (1) by increasing the distance between figure and screen since greater spatial separation should strengthen the segregation of both objects; and (2) by the use of screens of pronounced microstructure. In order to carry out the former experiment (Experiment 11), it was necessary to view the stimulus situation directly and not on the ground glass of the camera. Suitable measures were taken to avoid shadows on the disc as far as possible. A series of observations, made monocularly (but with good depth impression) by the staff at a distance of 2 m. from the disc, showed that the contours of the figure were still continuous when the depth separation was 1·5 cm. When the distance was increased to 16 cm. and 32 cm., all trace of figural continuity disappeared.

The results of reinforcing the surface colour appearance of the screen by the second method are given in the following experiment.

Experiment 12.

Experimental conditions. A bluish-grey screen with black letters printed on it was fixed to the ground glass. It was placed on the left side of the ground glass and presented simultaneously with the plain standard screen. The visible area of the ground glass was as in Experiment 6.

Subjects and procedure.—The subjects were the 19 practised observers of Experiment 6. The instruction was the same as in that experiment.

Results.

Table V summarizes the findings of this experiment.

TABLE V

A COMPARISON OF THE FREQUENCIES OF FORM COMPLETION RESPONSES WITH A STRUCTURED AND STANDARD PLAIN SCREEN

Screen	*N*	*Completion*		*Interruption*		?	
		f	%	f	%	f	%
Structured	19	8	42	8	42	3	16
Standard plain ..	19	18	95	0	0	1	5

A chi-square analysis of the frequencies of the completion responses with Yates' correction for continuity shows that the lettering on the screen obstructs the form continuity of the figure. Chi-square is equal to 8·1 which is significant at the 0·01 level.

A repetition of the experiment with a small fixation point on the bluish-grey screen brought no further reduction in the number of responses.

The influence of the shape and movement of the figure.

Rosenbach and Metzger accounted for the apparent transparency of the screen largely in terms of the shape, size and movement of the figure. Considerable attention was given to the first of these configural conditions at the beginning of the research. Triangles, hexagons, and circles were tried, but the rectangular form was found to be most satisfactory for our purpose. The remaining conditions, which both Rosenbach and Metzger alleged to be the primary factors in the form completion of the figure, were the object of our final experiment.

The width of the figure.

The relation of the width dimension of the figure to its form continuity is demonstrated in the following experiment.

Experiment 13.

Experimental conditions. The figures were of standard grey but of different widths: 4 mm., 12 mm., 25 mm., 40 mm., and 60 mm. A small dot was placed on the screen as a fixation point. The screen had a reflection factor of 0·19.

Subjects and procedure. The subjects were 5 members of the staff (Mi, Mo, Kn, Ge, Gl). The subjects made four observations on different days. All the figures were shown at each session, but in random order. The subject made his report after two presentations of the figure.

Results.

Table VI gives the results of this experiment.

TABLE VI

FREQUENCIES OF FORM COMPLETION RESPONSES WITH INCREASING WIDTH OF THE FIGURE

Width of the Figure (mm.)	*N*	*Absolute frequency*	*Per cent.*
4	20	3	15
12	20	19	95
25	20	16	80
40	20	9	45
60	20	8	40
	100	55	

If (55) (20)/100 is taken as the expected frequency of continuity responses for all widths, χ^2 is equal to 15·08 which is significant for 4 d.f. beyond the 1 per cent. level. Even with responses on the 4 mm. screen omitted from the Table, the χ^2 value is 12·2 (expected frequencies (52) (20)/100) is significant for 3 d.f. beyond the 1 per cent. level. The low percentage of continuity responses in the case of the 4 mm. screen and those of 40 mm. and 60 mm. resulted from different factors. The small size of the screen's area lying between the projecting parts of the figure at the crossing-point may have been the cause of the large number of negative responses in the first case. With screens of 40 mm. and 60 mm., the subjects could see the upper border and then the lower border of the figure as uninterrupted, but they could not generally see both as continuous simultaneously. It was to avoid confusing such reports of figural continuity with those which implied a simultaneous apprehension of both borders as continuous that a fixation point was placed on the screen. While this avoided one difficulty, it created another: it enhanced the surface colour appearance of the screen. This, as we have already noted, is detrimental to the figural completion.

To this experiment on the width of the figures we may append another concerning the induction effected on the screen when its upper half was presented against a stationary black background, and its lower half against a stationary white background (Experiment 13). The members of the staff unanimously reported a simultaneous brightness contrast effect: the upper portion appeared brighter. The border line separating the two induction fields was then given a swinging movement. Under this new condition, the observers reported a darkening which extended some distance upward on the screen from the point where the border of the figure swept past it. Some saw the darkening on the entire upper half of the screen. The study of the contrast reversal was pursued in a further experiment (Experiment 14). The figure was a dark grey area whose width varied constantly between 3 cm. and 6 cm. Thirteen untrained subjects were asked to observe the area of the screen at the crossing-point and report whether it appeared darker or brighter than the rest of the screen.

Three subjects reported no change whatever on the screen. Of the remainder 4 subjects saw the area at the crossing-point as darker than the other parts of the screen. The other 5 subjects reported the opposite.

These last experiments show that simultaneous brightness contrast is not compelling when the border lines of the inducing fields are in motion. Instead there may be an induction in the opposite sense. It is our opinion that the darkening, which consistently figures in the reports of the subjects under standard conditions, must be related to this effect of an inducing field which is in movement.

The extension of the figure on both sides of the screen.

A series of experiments were undertaken to discover the influence of the length of the figure on its form continuity. These experiments led to the same conclusion. Hence their results can be reported together.

Experiment 15.

Experimental conditions. The figures were standard greys with lines drawn on them in black ink. On one, the lines were vertical and were set 1 cm. apart. On the second, the lines were the same distance from each other but were slanted so that their entire length was 3 cm. They thus exceeded the width of the screen. The linear speed of the figure was reduced to 9 cm. sec.

Subjects and procedure. Four members of the staff (Mi, Kn, Ge, Gl) and two foreign psychologists (B and G), visiting the laboratory, served as subjects. The latter were given a series of practice trials with the plain standard figures before taking part in the experiment. Multiple presentations were given.

Results.

All the observers reported that the lines of 3 cm. length were continuous across the screen, whereas they saw nothing similar in the case of the vertical lines of the second figure. The darkening at the crossing-point appeared completely uniform.

Experiment 16.

Experimental conditions. The figure had a pattern of deep brown stars arranged quincuncially on a light background. Three stars formed a kind of diagonal which exceeded the width of the screen. The other conditions were as in the preceding experiment, except for the screen, which was black.

Subjects and procedure. These were the same as in the preceding experiment.

Results.

The four members of the staff reported that the star pattern could be seen faintly through the screen. The visitors saw some change in the darkening at the critical area which they described as a "flicker" or "irregularity" on that part of the screen.

Experiment 17.

Experimental conditions. A black cross of standard with (the length of the vertical arm was 15 cm. and that of the horizontal arm, 17 cm., the reflection factor was 0·04) was attached to the ground glass as a screen. The remaining area of the ground glass was left uncovered. The figure was a stripe of standard grey brightness (width, 4 mm.), which appeared on the right side of the ground glass as a tilted line. Its tilt gradually diminished as it moved across the field so that at the centre of the ground glass it was in a vertical position and thus covered by the vertical arm of the cross. As it moved across the left side of the ground glass, it again began to tilt, but this time in the opposite direction. The parts of the figure were thus visible on either side of the horizontal bar of the cross except at the middle of the ground glass. The translation speed of the figure was reduced to 4-5ths of its standard speed.

Subjects and procedure. Three members of the staff (Mi, Ge, Gl) served as subjects.

Results.

The reports of all the subjects were identical. The figure was seen as completed across the horizontal bar of the screen when parts of the figure extended on either side of it. As soon as it passed behind the vertical bar of the screen, all trace of the figure disappeared.

Conclusion.

Experiments 15, 16 and 17 fully confirmed that for a figure to be perceptually completed across the screen, its length had to exceed the width of the screen. The necessity of this configural condition appeared most strikingly in the case of Experiment 17 where the subjects could see continuity and interruption successively as the figure approached and passed the vertical bar of the screen. Although the natural expectancy was to see the stripe passing across the whole surface of the ground glass, it completely disappeared in the middle of the field.

The movement of the figure.

The first experiment on this factor consisted in the suppression of the apparent pivotal movement of the figure when it passed the screen (Fig. III). Arcs of 40° of standard grey brightness were used instead of the standard, tangentially placed, rectangular figures. The members of the staff, who served as subjects, reported that the figures were completed across the screen, but added that the continuity was less impressive than when the figure seemed to make a pivotal movement while crossing the screen.

A second experiment was undertaken to study the influence of the speed of the movement of the figure on its form completion.

Experiment 19.

Experimental conditions. We compared the impressions which were given when the figure was stationary with those which arose when it was set in movement at the following linear speeds (cm. sec.): 1·1, 3·5, 9, 18, 28, 47, 53, 68, 76. (All the brightness conditions were standard.)

Subjects and procedure. The subjects were those of Experiment 6. They were instructed to report whether the figure appeared continuous or interrupted in form for each change of speed. The first setting of the figure was at 0. Its speed was then increased successively to 76 cm. sec. A second descending series followed. Thus for all settings there were 38 responses except in the case of 0 and 1·1 cm. sec. Ten subjects reported on the first setting and 18 subjects on the second.

Results.

The frequencies for the various kinds of responses are given in Table VII. If the expected frequencies are computed by taking percentages of the total number of completion responses, the χ^2 value is 11·45. This gives a probability equal to 20 for 8 d.f. In consequence there is no proof that any particular speed significantly favours the continuity response. It should be noted, however, that this conclusion is based on the reports of subjects who were familiar with the experimental task. The distribution of the frequencies suggests that the mean speeds might be significantly more favourable than the others if the experiment were performed in less practised subjects. This hypothesis is supported firstly, by some informal trials with subjects of this kind, and, secondly, by the observations of the members of the staff. The reports show that the form completion was most in evidence with mean speeds of the figure. With faster speeds, they noted that it degenerated into an unshaped darkening.

These experiments on the configurational conditions of the figure and its movement indicate that the projection of the parts of the figure on either side of the screen and their participation in a common movement across the field are the unifying factors principally responsible for the extension of the brightness situation, existing between the figure and the background, to the screen. We have not been able to discover any specific factors, apart from repetition, expectancy and possibly speed which would account for the transition from the initial vague darkening (contrast reversal) to the responses of shaped darkening and of transparency. We have had occasion to notice, however, that the latter response occurs generally with trained observers and is strongly influenced by past experience.

TABLE VII

Frequencies of Form Completion, Interruption, and Doubtful Responses with Increasing Linear Speed of the Figure

Linear speed (*cm. sec.*)	*N*	*Completion*		*Interruption*			
		f	%	*f*	%	*f*	%
0	20	8	40	7	35	5	25
1·1	36	16	44	19	53	1	3
3·5	38	18	47	19	50	1	3
9·0	38	28	74	10	26	0	0
18·0	38	30	79	7	18	1	3
28·0	38	32	84	6	16	0	0
53·0	38	28	74	7	18	3	8
68·0	38	23	60	12	32	3	8
76·0	38	21	55	10	26	7	18
	322	204					

V

Conclusion

We are now in a position to evaluate our initial hypothesis that the "screen effect" and the "tunnel effect" might be related to Rosenbach's case of apparent transparency. If such a relation exists, it is to be expected that the stimulus conditions of all these phenomena would be, to a large extent, similar. Our systematic study of the apparent transparency shows that there are only two such conditions which it possessed in common with the "screen effect" and the "tunnel effect": firstly, the system of stimulation must be such that the common separation line between the figure and the screen appears to belong exclusively to the latter; and, secondly, the visible parts of the figure must lack adequate closure and demand a completion to appear as closed forms. There is an additional condition which the apparent transparency shares with the "tunnel effect." Both phenomena require a narrow screen with movement of the figure on either side of it. Apart from these similarities, the stimulus conditions of the Rosenbach phenomenon are entirely different from those of the two others. These points of difference may be briefly summarized as follows:

(1) The brightness gradient between the figure, screen and background is of primary importance for the apparent transparency while it has practically no influence on the "screen effect" and the "tunnel effect."

(2) A thin line or point can serve as the moving object in "screen effect" and "tunnel effect." This is not true in the Rosenbach phenomenon where the width dimension of the figure contributes to its form completion.

(3) A "screen effect" or "tunnel effect" can readily be had with outlines of figures. On the other hand, it is extremely difficult to see such figures as completed in form under Rosenbach's conditions.

(4) The extension of the figure across the screen has no part in the "screen effect." The impression of "sliding behind" can be given by progressively diminishing the length of the moving figure as soon as it has attained one side of the screen.

(5) The speed of the object's [translation] movement is only of relative importance in the Rosenbach phenomenon, whereas it is a basic condition of the continuity of the movement in the "tunnel effect."

This comparison of the objective factors which control these phenomena, indicates that the relationship between them is more apparent than real. A further consideration will establish this clearly. When naïve subjects are confronted with the stimulus situation proper to the "sçreen effect" or the "tunnel effect," they spontaneously give an appropriate response. The objective situation is coercive. The apparent transparency, on the contrary, demands an adequate "set" and a certain period of training even under optimum physical conditions. This need of preparation, in addition to the complex stimulus pattern which it requires, is sufficient ground for concluding that it represents a form of structural organization entirely distinct from the others. There is thus no real continuity between the "modal presence" of the hidden part in the Rosenbach phenomenon and its "amodal presence" in the "screen effect" and the "tunnel effect."

This article is an extract from a dissertation submitted to the University of Louvain. The writer is deeply indebted to Professor A. Michotte who directed the investigation.

REFERENCES

BURKE, L. (1952). On the tunnel effect. *Quart. J. exp. Psychol.*, **4**, 121–138.

KNOPS, L. (1947). Contribution à l'étude de la "naissance" et de la "permanence" phénoménales dans le champ visuel. *Miscellanea Albert Michotte.* Louvain.

METZGER, W. (1936). *Gesetze der Sehens.* Dresden.

MICHOTTE, A. (1950). A propos de la permanence phénoménale: faits et théories. *Acta Psychol.*, **7**, 298–332.

ROSENBACH, O. (1902). Zur Lehre von den Urtheiltäuschungen. *Z. Psychol.*, **29**, 434–448.

SAMPAIO, A. C. (1943). *La Translation des Objets comme Facteur de leur Permanence Phénoménale.* Louvain.

ZEITSCHRIFT FÜR EXPERIMENTELLE UND ANGEWANDTE PSYCHOLOGIE

(*Journal of Experimental and Applied Psychology*)
Organ der Deutschen Gesellschaft für Psychologie

Herausgeber für Deutschland
Prof. Dr. J. von Allesch, Göttingen; Prof. Dr. Ph. Lersch, München

Herausgeber für Österreich
Prof. Dr. H. Rohracher, Wien

Herausgeber für die Schweiz
Prof. Dr. R. Meili, Bern

Redaktion
Dr. C. J. Hogrefe, Göttingen

Band II, Heft 2, 1954

G. EKMAN, Eine neue Methode zur Erlebnisanalyse.
F. SÜLLWOLD, Experimentelle Untersuchungen über die Rolle des Einfalls im Denkprozeß.
K. SCHOTT, Zur Psychologie der Sprechspur.
A. LEISER-EGGERT, Methodische und statistische Untersuchungen zum Problem der Lateralisation.
W. KÜPPERS, Geistige Tätigkeit und galvanisches Phänomen.
A. SCHLISMANN, Die Sprache im Test als Basis objektiver Messung.

All articles are provided with summaries in English and French.

The journal appears quarterly and contains 160 pages. Subscription is DM 64.— per volume and DM 18.— for single numbers.

VERLAG FÜR PSYCHOLOGIE · DR. C. J. HOGREFE · GÖTTINGEN
(Germany) · Postfach 414

MARIA MONTESSORI TRAINING ORGANISATION

1, Park Crescent, London, W.1 (MUSeum 7425)

34th Montessori International Diploma Course: 29th Sept., 1954, to 31st March, 1955.

Short Course: 29th Sept. to 18th Dec., 1954.

Lectures three evenings per week, and practice with apparatus under the personal supervision of qualified tutors. Facilities for observation and research.

These are the only Courses in London authorised by the International Montessori Association (A.M.I.), embodying much new material in scientific pedagogy and child psychology. In addition to the care, education and psychology of the normal child, the lectures will include the application of the Montessori Method in the treatment of spastic cases, mentally deficient, retarded and maladjusted children. Prospectus from the Secretary.

THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY

The Quarterly Journal of Experimental Psychology is published for the Experimental Psychology Group by W. Heffer & Sons Ltd., Petty Cury, Cambridge, England, to whom all business communications should be addressed.

The subscription is £1 10*s*. 0*d*. (post free) per volume of 4 numbers. Numbers appear quarterly. The cost of any single number is now 10*s*. 0*d*. (postage 2*d*.).

Undergraduate and graduates of less than three years' standing are offered a special rate of 15*s*. 0*d*. per volume. They should apply to the Editor, enclosing a remittance for 15*s*. 0*d*. and stating in which university department they have worked and what year they expect to graduate or did graduate.

All other subscriptions and orders should be placed with W. Heffer & Sons Ltd., or any bookseller.

★ ★ ★ ★

Papers submitted for publication and all other communications on Editorial matters should be addressed to "The Editor, *Quarterly Journal of Experimental Psychology*, Psychological Laboratory, Downing Street, Cambridge, England."

Only original papers are accepted for publication. The copyright in any material accepted for publication is retained by the *Journal*. Reproduction in whole or in part is forbidden, except (1) under terms of the *Fair Copying Declaration* of the Royal Society, or (2) when specific permission has been given by the Editor.

Intending contributors should pay attention to the conventions of the *Journal*, and especially to the form in which references are given. Manuscripts should be typewritten with double spacing and with wide margins. Diagrams, which should be kept to the minimum, must be submitted in a form suitable for reproduction without redrawing. They should be drawn in black ink on heavy paper; lettering should be inserted not on the diagram but on a tracing fixed over the diagram. Legends and tables should be typed on separate sheets of paper.

Contributors receive 20 copies of their paper free. If they require further copies they should apply to the Editor at the time of returning proofs.

PRINTED BY W. HEFFER & SONS LTD., CAMBRIDGE, ENGLAND